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MODERN STEAM POWER STATION DESIGN.*

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INTRODUCTION.

THE reliable and economical production of power is one of the most vital subjects with which a public service company has to deal today. Always of importance, it has become doubly so now, with the high cost of labor and the growing scarcity and high price of fuel, and much careful study is being given the subject with a view to increasing economies of operation by improvements in design of plant and equipment and by bettering of load factor through centralization of power generation.

In like manner, but to a lesser degree, is this subject of importance to the large industrial companies. With them power is only one of the many items entering into the cost of a manufactured article and does not constitute their chief product, but increasing costs have had their effect on them too, and we find them more and more becoming either customers of the central station, or where they have need of much steam in their processes, paying particular attention to the design and operation of their generating equipment.

HISTORICAL.

At the time of the coming of the steam turbine, not much advance was being made in the art of power station design.

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Although several large and quite economical engine-driven stations had been built, they consisted principally in a repetition of practically standard equipment, and succeeding installations did not represent much advance over preceding ones. Electric drive of industrial equipment was not common and central stations supplied power principally for street railways, lighting and comparatively small motor installations.

The economical range of distribution was usually small, requiring a number of stations often unsuitably located for economical generation in an area that could be properly supplied from one or two turbine stations today. Most industrial plants had their own power stations, consisting generally of fire-tube boilers and noncondensing engines belt connected to long line shafts. Often the engines were located in parts of the factory remote from the boilers and connected with them through long steam lines.

The commercial adoption of the steam turbogenerator completely changed the existing order of things and so increased the importance of other power plant equipment as to make radical development necessary to adapt them to the new conditions. Essentially an alternating current piece of equipment on account of its high speed, the turbogenerator gave great impetus to the use of alternating current and in conjunction with the transformer increased the range of power distribution, permitting greater centralization in the generation of power with consequent greater latitude in the selection of a suitable site for the station.

The ability of the turbine to use superheated steam, higher steam pressures, and particularly high vacua with consequent great increase in economy, led to the adoption of the superheater, the almost universal use of the water-tube boiler and to great improvements in the design of condensing equipment. These things, together with the changes in type, size and speed of the prime mover, introduced new factors in power station design and made radical changes necessary.

The old idea, however, of uniform arrangement and repetition of equipment, common in engine stations, still prevailed and we find the early design of steam turbine stations based on the continued installation of the same type and size of equipment. Thus stations were laid out for vertical or for horizontal units, it being assumed that each succeeding unit would be similar in all respects to those previously installed.

IMPETUS DUE TO STEAM TURBINE.

The great increase in the use of central station power, and the greater economies in space and steam consumption lead to the design and installation of larger and still larger units, until today we have stations built and projected, with capacities of over 200,000 kw., and occupying space originally intended for half the capacity and with operating efficiencies considered impossible in the early days of the industry.

The Fisk Street Station in Chicago, the first of the large stations designed for steam turbines, was originally laid out for 5000 kw. units, considered in those days to be the largest size practical. Within six years, however, these were replaced by units of 12,000 kw. capacity and of sufficiently better steam consumption to make the substitution financially economical. After the installation of ten of these units, a 25,000 kw. unit was installed, followed by a 20,000 kw., a 30,000 kw., and a 35,000 kw. unit, making a total installation today of 230,000 kw. in a space originally intended for 70,000 kw. Other equipment in the station naturally had to keep pace with the increase in sizes of the main units. The boiler plant was started with 500 h.p. units, to be followed by 1200 h.p. and 1450 h.p. units.

PRESENT STATUS OF TURBINE DESIGN.

Experience with the operation of the larger size units within the past few years has brought out the fact that while they have justified themselves from the standpoint of economy of steam consumption and space occupied, they have not at the same time shown the reliability of the earlier and smaller units. The greater diameters and higher peripheral speeds of the larger units have magnified the importance of vibration, temperature changes, and other factors not so seriously affecting the smaller units. The fact that the rapid increase in size of units occurred during the war period when the quality of labor was poor and when quantity rather than excellence of production was the rule, has probably contributed to the difficulties experienced. There has, therefore, been a halt in the increase of size of individual units, and attention is being given to correcting difficulties and improving existing designs rather than planning for larger capacities. There is a feeling also that the economies of operation and space of still larger units are not commensurate with the investment tied up

in them and the large loss when they are not in service. We have reached a point where the economies to be gained from further increase in size of units seem not to be warranted. It may be that the working out of a super-power system, as is now proposed, will cause us to go to larger sizes, but for the present the economical limit appears to have been reached.

TWO SIDES TO STATION DESIGN.

There are two principal sides to the design of a steam power station, the economical and the mechanical. The first deals with the selection of the equipment and the working out of the station heat balance to give a kilowatt hour for the least cost; the other deals with the design of the structure and the arrangement of the equipment to give maximum ease of operation and maintenance. The first sets the station bogey, that is, it fixes the limits of economy possible with any given condition of operation. The second affects the cost of the station and therefore the fixed charges. There are more ways of solving the problem with consequently more chance for controversy as to the relative merits of various solutions. Different engineers treat the problem differently and local conditions often play such an important part that one cannot generalize and say that one type of arrangement is better than another. There are certain principles that apply to the general subject, however, that can be stated without risk of an argument.

I. ECONOMICAL FEATURES OF DESIGN.

Size and Characteristics of Load.

The first things to be determined in the design of a central station are the characteristics of the load, the load factor and the present and probable ultimate capacity to be provided. Each community, or industry, furnishes a typical load curve from which a start can be made. The load curve should cover as long a period as possible. From this the characteristics of the load, the load factor and the rate of growth can be approximately determined. With this as a basis, and modified by the possibilities of future increase of load, the size of the first installation and the probable ultimate capacity of the station can be decided.

Selection of Site.

The next important consideration is the selection of the site. Before any property is purchased for power station purposes, its

suitability from an engineering standpoint should be determined. Sometimes when he approaches the question of power station design, the engineer finds the site has been selected for him and is forced to make the best of what has been provided. This throws a handicap on the working out of a suitable design and may seriously affect the amount of the returns on the investment. Chief considerations in the selection of the site are the adequacy of water supply for condensing purposes, accessibility by rail or water, or both, for the delivery of fuel, and the location with reference to the delivery of the power generated. The site should be of ample area for the scope intended up to the ultimate capacity, including space for coal storage and outside electrical switching and transforming equipment. It is not always possible to procure a site, especially in the larger cities, that possesses all the requirements and is at the same time within economical transmission distance of the load. In this case it is necessary either to sacrifice some of the considerations or make provision for them elsewhere. In New York and Chicago, and in your own City of Philadelphia, sufficient areas are not available near some of the power station sites for the storage of emergency coal, and it has been necessary to provide for this on property remote from the stations.

A careful study should be made by means of borings, test pits, and test piles to determine the soil conditions and to decide on the type of foundations to be used. This study cannot be too carefully made, for upon the type of foundations used depends the stability of the structure, the speed of construction, and the cost of the work. I have in mind a case, in the construction of the new Delaware station of The Philadelphia Electric Company. This station is located on the Delaware River, on the site of the old Neafie and Levy shipyard. Core borings, made at regular and close intervals over the lot, showed rock in the form of a mica schist at an average depth of about forty feet below mean water. Above this were layers of sand, mud, silt and general river débris. Closer to the surface was an immense mass of timber in the form of individual sticks and arranged in cribs for shipways. After a careful study by the company's engineers, the architects and the constructors, it was decided to carry the foundations to rock. This was done by driving open circular caissons of steel sheet piling down to rock, then excavating and filling them with concrete. The wisdom of the method was early demonstrated by the speed and

ease with which the difficult work was done. In some places timber cribbing twelve feet thick and in a perfect state of preservation was driven through. The result was a great saving, both in time of construction and in the cost of this work.

Location on Site.

A study should be made of the location of the station on the property. This should be done in conjunction with the working out of the design and will be affected by the shape of the lot, flow of the stream, the manner in which fuel is received and the effect of the various locations on the cost of the plant. Recirculation of condensing water should be guarded against by proper arrangement of intake and discharge tunnels. Ease and speed of fuel handling into and out of storage must be considered, and also proper allowance made for electrical getaway, either underground or overhead, as required. Where, as is usually the case, the ultimate installation is to be made in steps covering a period of years, the size of the first step will have some bearing on the type of design and the location on the site. Investment should not be made for more construction, or for the installation of any more equipment than is required for the step under consideration unless the rate of growth is such that the need for the additional installation will be soon realized, or unless it can be provided at comparatively slight additional expense and the expense if deferred would be much greater. Very often the design can be workd out so that provision for future installation can be made at slight additional expense and the actual installation deferred until it is needed. I refer to such items as screen wells, condensing water tunnels, coal and ash handling equipment and bus bar and other electrical work. A so-called " Unit System " of design would seem to best meet this requirement.

Flexibility in Design.

The design should be sufficiently flexible to readily adapt itself to changes and advances in the art. We have seen rapid strides in the art of prime mover design in the past ten years and engineers have had their ingenuity taxed to harmonize additions to existing plants and to substitute larger units in the place of existing smaller ones. I have in mind a case where a large sum was spent to change existing steelwork and building structure to accommodate larger

boilers than were considered feasible when the building was constructed. Although we seem to have reached a pause in the increase of size of units, larger ones may come. We already have units of more than one cylinder arranged in tandem with one generator or in multiple with each cylinder driving a separate generator and we may come to still more modifications. Experiments have been conducted for some time on the mercury boiler and turbine in combination with a steam turbine and a trial commercial installation has been arranged for. Although not yet developed to a point where its general adoption is in sight, at the same time the efficiencies to be expected are such as to warrant its development and make future installation possible. While it is obviously impossible to make detail provision for such future development, the possibility of its installation should be recognized in the general development of the design.

Reliability of Service.

Reliability of service is the first requisite of a modern power station. It must be able and ready at all times to supply power in the amounts demanded. Increases in load must be anticipated by a careful study of the rate of growth and probable additions of load, and installation of equipment made in time to provide the capacity to care for load. There ought to be no limit to which we should go in insuring safety and continuity of service except that placed by the volume of the business. We can best provide for such service by the choice and arrangement of equipment that will be least liable to fail through accident or wear and by the installation of proper reserve capacity to take the load in case of failure and to permit the withdrawal from service of each piece of equipment at regular intervals for inspection and repair.

Continuity of service is affected by the amount of labor required in the operation of the equipment. This should be borne in mind in determining the length to which to go in installing labor-saving equipment. In case of labor trouble, the fewer men one has to replace in an emergency, the better is the continuity of service safeguarded. While not a controlling feature, this fact should not be lost sight of.

Ruggedness of design and number of parts subject to wear are important items in the selection of a unit. The conditions under which each piece of equipment will have to operate must be deter-

mined and choice made of the one that will best meet these conditions. In asking for quotations on equipment it is best to prepare a specification covering the essential requirements to be met and stating the minimum size of equipment that will be acceptable for the service. Sufficient data should be furnished by each manufacturer to permit of a complete comparison of the propositions received. These data should include, beside the price of the equipment, a detail description of the essential features of the design and the operating results to be expected under the stated load conditions.

DETERMINATION OF SIZE OF EQUIPMENT.

The determination of the size of equipment to accomplish a given result is an economic proposition dependent on certain fixed conditions.

Take, for example, a surface condensing equipment for a given turbogenerator. The steam to be condensed is a function of the vacuum which in turn depends upon the condensing surface and the amount and temperature of the condensing water. The temperature of the water varies from month to month and therefore the vacuum and amount of steam to be condensed for a given load on the turbine will vary. Conversely the amount of water required for a given vacuum will vary with the temperature of the water. The rate of heat transfer will vary as the tubes become dirty and will affect the vacuum. Load factor and station heat balance also affect the size of the condenser and the type of its auxiliaries, and it is for the engineers to decide how to best meet these conditions. Unless given certain stated conditions the manufacturer will naturally and properly assume conditions best suited to his equipment without regard to its effect on the subject as a whole.

Selection of the sizes of units will depend upon the character of load, peak load, rate of growth of load and load factor. For the smaller stations, the character of the load and shape of load curve influence the selection of units more than anything else. In this case the selection of the sizes and number of units will depend on the relation of peak to base load, duration of the minimum load, relative costs and economies of the units and the spare capacity required. This last should be equal to the capacity of the largest unit in the station. If the system be a small one with a single station and an ordinary light and power load, the first installation

would probably consist of two or three units. If two units are installed they would be of the same capacity, and each would be large enough to carry the peak load. If three units are installed, two would be of the same size, each of capacity sufficient for the day or base load. The third would be of less capacity or large enough to carry the night or minimum load and in conjunction with one of the larger units to carry the peak load. If the night or minimum load were sufficiently large, the three units might be the same size. As the load grew the sizes of units in each successive installation would be increased, the size of unit for each step being determined by the day or base load until the load has increased to a point where it equals or exceeds present maximum unit capacities or until nothing appreciable is to be gained in station economy by increasing the size of units. Beyond this point, and for the larger stations in which the load exceeds the present maximum unit capacities, the number and sizes of the units will be governed by operating practicability and flexibility.

Rate of growth of load has also considerable influence on the size of unit. A fast growing load means a rapid increase in station capacity to keep pace with the load. The smaller the size of each additional installation the shorter the intervals between the steps in the development of the plant. Larger units will cost more in total amount but less per kilowatt to install than the smaller ones and will increase the time until the next installation must be made. They mean a greater investment at each installation but fewer steps and a longer period between steps. They require fewer steps for a given development and the total cost for a given capacity will be less than with the smaller units. There will also be some operating economy to be gained on account of the greater efficiency of the larger units. The most economical size of installation to make, however, can only be determined by considering the investment and the operating economies in conjunction with the rate of growth of the load. The more rapid the growth the greater will be the increase in size of each succeeding unit up to the maximum.

Effect of Load Factor on Design.

I have previously made several references to load factor as affecting certain phases of power station design. Load factor is the starting point in the consideration of the economics of power

station design, and enters into practically every step from the choosing of the site down to the selection of the smaller pieces of equipment.

The output of a power station varies in accordance with the instantaneous demand. Power must be generated as it is used. It cannot be generated and stored during a period of low demand, as can gas, to be used to supplement production during a period of peak load, or at a time of minor interruption to production.

"Load factor" is the measure of the uniformity of production. It is defined as the ratio of the average rate of output to the maximum during a given length of time, and is stated as "daily load factor," "monthly load factor," or "yearly load factor," based on the period of time covered. The duration of the maximum demand is usually specified, such as "quarter hourly," "half hourly," or "hourly" demand. It indicates the plant's ability to carry the peak load over an appreciable period of time as distinguished from a momentary swing. Load factor may be applied to a plant as a whole or to any one generating unit.

The higher the load factor, or the more nearly continuous the output, the more are unit costs of production reduced through:

Increased operating efficiency of equipment.
Labor costs not rising in proportion to increased output.
Little, if any, increase in cost of superintendence and overhead expense.
Fixed charges being distributed over a greater output.

Load factor in itself is not a complete indication of operation conditions without the load curves from which it is obtained. Two load curves may give the same load factor and yet have essentially different characteristics. For instance, an intermittent load requiring full power for brief intervals throughout the day may give the same load factor, but impose very different operating conditions from another load of the same maximum demand in which the peaks were not so frequent and the base load uniform. This condition, however, is more liable to occur in a plant supplying power for an industry than in a plant supplying a community where the diversity is greater. An example of this fact is found in a plant recently installed for a factory in which the main load consisted of a number of large motors of from 600 h.p. to 700 h.p. each. These are operated intermittently for periods of about an hour each and not in accordance with any fixed schedule. The

result is a fluctuating load without any regularity requiring the plant at all times to be ready to take the maximum load, although operating most of the time at considerable less than maximum. The load factor for this plant may be better than one in which better economy is obtained for the reason that operating conditions are more constant over greater periods.

A high load factor means that more investment may be economically made in providing equipment of higher efficiency, the increased fixed charges being more than offset by the saving in operating expense. The more nearly continuous use of the equipment incident to the higher load factor would warrant the installation of fewer and larger units of greater economy, more liberal provision in condensing equipment, larger boilers run at lower and more economical ratings and possibly economizers or additional heating surfaces in boilers in the form of more and longer tubes in the path of the gases from furnace to uptake.

In making an analysis of load factor, especially in the case of a growing load, the length of service of a unit or a station at the load factor determined should be carefully estimated, in order to avoid serious error due to a change in load factor as the age of the equipment increases. Almost always a unit, or a station, is operated at its highest load factor during the few years immediately following its being put into service. At this time it usually represents the highest state of the art and is in the best of operating condition. As time passes, advances in the art produce better units, and even with the best of care the operating efficiency of the unit decreases, therefore when additions are made the base load and consequently higher load factor passes to the newer and more efficient equipment, and the older is used more and more for peak load or standby service. The load factor is consequently decreased and it is not possible to realize the economies of the high load factor operation. The fixed charges on the investment for the high load factor condition become a loss, compensated for in only a small way by the use of more economical equipment at the low load factor. Careful consideration and good judgment on the part of the engineer responsible for the design is required in order to make possible the maximum net return throughout the life of the equipment.

Load factor influences the choice of a station site by limiting the distance from the load it will be economical to go to obtain

adequate condensing water supply. The combining of individual systems into groups, such as is frequently done, is all in an effort to obtain greater economies through better load factor with consequent greater latitude in the selection of suitable station sites.

Load factor influences the selection of the size and type of equipment to be installed by fixing the extent of use of the equipment and consequently the economies to be attained. Generally speaking for the main units, the higher load factor warrants the installation of larger units up to the limits prescribed by the peak load and the existing state of the art.

The boiler plant is usually operated with respect to the station load rather than the loads on the various units.

The boiler room equipment to be installed will therefore be governed more by station load factor than by the load factor on any one unit. The number and size of boilers will depend upon the contemplated ultimate station capacity, the rating at which they will be run, and upon the sizes of the main units. Usually only one capacity of boiler is contemplated, although in some of the older stations that have passed through the rapid development period in main unit design, the capacity and type of boilers have been changed.

The ratings at which the boiler plant will run will depend upon the shape of the load curve and the station load factor. It is a question of comparing the fixed charges with the cost of operation and maintenance to be obtained from different numbers of boilers under the conditions imposed by the load factor. The higher the load factor the more boilers will it be economical to install that they may be run the more nearly at their most efficient rating. A low load factor usually means a shorter peak load, therefore, it is more economical to install less boiler capacity and increase the rating over the peak.

The selection of the type and details of design of the boiler depend upon its efficiencies at the ratings at which it will operate, the steam pressure, and the character of the feed water. A boiler in which the tube surface and baffling is arranged to give maximum effective passage of gases through the boiler with consequent greater heat absorption will be the most efficient type. A boiler requiring no stayed surfaces has decided advantages over others at the high pressures now coming into general use. A boiler with straight tubes is easier to keep clean and less liable to scale

and prime under poor feed water conditions than one with curved tubes.

The installation of economizers in conjunction with boilers is a question of boiler rating, station load factor, heat balance and cost of fuel. A high load factor or high fuel cost warrants the installation of more equipment to obtain greater economy. Economizers are merely additional heating surface placed in the path of the gases after they have passed over the boiler surface, and through which the feed water is passed on its way to the boiler. The ratio of economizer surface to boiler surface is based on so proportioning the heating surface between the two as to obtain the maximum heat absorption for a given cost. The performance of an economizer is dependent on the temperature of the entering feed water, the temperature of the flue gases leaving the boiler and the amount of surface. Temperature of feed water is determined by the station heat balance, which is influenced in the case of stations having steel tube economizers by the necessity of keeping the entering temperature high enough to preclude pitting of the tubes. The temperature of the gases entering the economizer is dependent on the type of boiler, arrangement of baffling and the rating at which it is running. The amount of economizer surface depends on load factor and the cost of fuel. The amount of the heat rejected in the flue gases depends on the load factor and a high fuel cost increases the value of the heat thus rejected and makes it worth that much more to reclaim them. The amount of surface it is economical to install will depend on the cost of the additional equipment, its operating cost and the value of the heat reclaimed. In making this determination it is well to cover a considerable interval of time and to take into consideration the probability of fluctuations in the cost of fuel. Fixed charges on the additional investment will remain the same, but a decrease in fuel cost or a lowering of the load factor will mean less value of the heat reclaimed and the installation may be a net loss. This is especially true at the present time when prices are on the down side of the peak and when it is reasonable to expect that installation costs will be less in the future. A compromise might be to make provision in the design but postpone the installation until some future date, when prices are more stabilized and the economies to be obtained give promise of being permanent.

Selection of Auxiliary Equipment.

The selection of other power station equipment such as heaters, pumps, exciters, etc., depends on reliability and flexibility and on load factor through its effect on the station heat balance. A high load factor requires more nearly continuous operation of auxiliaries and gives less chance for making minor repairs during off peak periods. The reliability must therefore be greater.

Heat Balance.

The production of electrical energy in a steam power station is the result of a combined number of thermal operations and conversions of energy. Chief among these are the generation of steam by the combustion of the fuel and its utilization by the main units in the production of electrical energy. In addition there are the operations of the auxiliary equipment necessary for the support and continuance of the main operations, and for the recovering of the energy rejected by the equipment.

Heat balance is an analysis of the thermal processes taking place in a plant from the combustion of the fuel in the furnace to the production of electrical energy by the generator. It indicates the distribution of the energy produced by combustion among the different pieces of equipment accounting for that portion which is usefully employed and for what is thrown away. It is the power station energy balance sheet. Its careful study is therefore necessary if the most economical installation is to be made and many trial balances may be required before the answer is obtained.

Operating Pressures and Temperatures.

Among the first things to fix upon in the working out of a heat balance, and in fact, in the design of a station, are the operating steam pressure and temperature.

The theoretical efficiency of a steam turbine is the ratio of the difference between the total heats of the initial and final conditions to the total heat of the initial condition minus the heat of the liquid at the final condition. The lower limit is expressed by the exhaust steam temperature and is fixed by the vacuum in the condenser. This is dependent on the temperature of the condensing water and the amount of tube surface. The temperature of the water fixes the maximum vacuum possible and the load factor determines the economical amount of tube surface to install. The practical lower

limit to the temperature can be said to have been reached, and it is only by increasing the upper limit that betterment of efficiency can be obtained.

Theoretically for any given initial temperature the greater thermal efficiency is obtained with high pressure saturated steam. But two principal reasons prevent the maximum theoretical efficiency from being realized. First, the design and construction of equipment and piping have not yet reached the point to withstand the pressures of very high temperature saturated steam generation; and second, saturated steam, while theoretically the most efficient, is in actual use subject to losses through condensation, greater friction, etc., that render its use less economical. It therefore becomes necessary in practice to effect a compromise, adopting a working pressure that is practical from an operating and construction standpoint and superheating the steam to attain the maximum feasible temperature range and reduce losses due to friction and condensation to a minimum. Two hundred pounds was looked upon as a reasonable and economical working pressure eight years ago. Today we have a number of plants operating at 250 lb., several at from 275 lb. to 300 lb., and two or three at over 300 lb. Present designs of boilers are adaptable to pressures up to 400 lb. without radical changes, and turbine manufacturers state they can design units for any pressure the boilers can develop. Pressures and temperatures existing today do not cause particular troubles with steam piping if care is exercised in the design of the system and in the choice of materials. Ample provision should be made for expansion and flexibility between anchorage points by means of easy bends and turns. Superheated steam has caused the adoption of cast or wrought steel for all pipe flanges and of cast steel for fittings and valve bodies. Monel metal or nickel bronze is used for valve seats, discs and trimmings. Velocities of steam have been increased in turbine plants until in some cases we find them as high as ten to twelve thousand feet a minute.

Existing designs of equipment permit the use of steam temperatures up to about 650° or 700° F., without serious trouble. Above this temperature, however, present designs begin to give trouble.

Except at high ratings this temperature is difficult to obtain in the ordinary boiler setting with the superheater located at the top

of the first pass or in the second pass. In the most recent designs of boilers of the B. & W. type with high tube banks, the sections are being divided and the superheater placed in the first pass part way down from the top of the tube bank. This insures the maximum temperature of superheat at lower rating.

The present state of the art therefore may be said to permit of the economical adoption of pressures not exceeding 350 lb. pressure and temperatures up to 700° F. Conservative design would place the present limit at about 300 lb. and 650° F. There are stations projected abroad in which the steam conditions are higher than have been attempted here. The equipment, however, is of special design and construction, costing more to build and install, and made economical only by the higher price of fuel.

Effect of Type of Auxiliary Drive on Heat Balance.

There should always be sufficient duplication of auxiliary equipment to insure reliability of service at all times and to give sufficient flexibility for economical operation. Spare auxiliary equipment, or equivalent, is as essential as reserve main units.

Methods of drive for the auxiliary equipment vary from "all steam" to "all electric" with variations and combinations of the two. Each combination furnishes a heat balance showing the performance of the equipment under the load conditions and indicating the most efficient points of operation, together with the energy utilized and that thrown away. Comparison of the heat balances of the various combinations will indicate the most economical one to use.

The great proportion of energy rejected in the generation of electrical power occurs in three processes:

1. In the circulating water used for condensing the steam from the main units,
2. In the flue gases from the boilers, and
3. In the exhaust from the steam-driven auxiliary units.

The energy rejected in the circulating water represents the greater part of the total heat generated and is not recoverable. The energy in the flue gases can be recovered in part, and in so far as it is economical to do so by the use of economizers for heating the feed water or the air for combustion. That in the exhaust

from the auxiliaries can be recovered by heating the feed water or at certain loads by use in the lower stages of the main unit.

Electric energy used to drive auxiliary equipment can be obtained either from the main unit, from an auxiliary unit installed for the purpose, or from both. Where the auxiliary drives are both steam and electrical, the current is generally supplied by the main unit. Where the drive is all electrical the current is usually taken from an auxiliary unit or "house turbine." In this case the house turbine exhausts into a heater condenser of the jet type where the steam mixes with and heats the boiler feed water. In this manner the heat rejected in the exhaust steam is recovered. Recent designs for all electric drive contemplate a general duplication of auxiliary equipment driving part with current from a house turbine and part from the main unit. In this case part of the steam for heating the feed water is extracted from the main unit and condensed in an auxiliary condenser using condensate for the purpose. This method insures reliability of service by having two independent sources of power for drive, but introduces some complications on the electrical side by the duplication of switching equipment and buses, necessary to give the flexibility of operation desired. The extraction of steam from the main unit does not materially affect the economy of the main unit as the lower stages of the unit are less efficient at full load due to crowding of the steam. Extracting a portion of this steam permits more efficient use of the remainder in the lower stages and the energy of the steam extracted is all returned to the system through the heating of the feed water.

The final temperature to which the feed water should be heated and therefore the selection of the proper heat balance depends upon the use of economizers. Without economizers the temperature will be kept as near 212° as possible. With economizers it will probably be more economical to keep the feed temperature lower than 212° to permit of greater heat absorption by the economizer.

Choice of Fuel.

Fuel is the greatest item of expense (exclusive of fixed charges) in the generation of power, its cost in a modern central power station seldom being less than eighty per cent. of the cost of operation and maintenance. The choice of the fuel, therefore,

has a decided effect both on the boiler room equipment and on the station economy. On account of its great quantity and wide distribution coal is, of course, the most used fuel. Oil has been used for fuel for a number of years principally in territories close to the oil fields, and more recently in localities more remote from the coal fields and where there is water transportation. Natural gas is used in some localities as are hogged fuel, and other combustible residue from various manufacturing processes. But coal may be called the standard fuel, and any station that is built should be so designed and constructed that coal-burning equipment can be installed without radical changes, no matter if some other form of fuel may prove more economical for the time being. By so doing one does not put himself under the obligation to use any fuel longer than it is economically possible to do so.

Coal.

Coal is mined in practically every section of the country except the New England States and every locality may be said therefore to be within reasonable distance of a supply of some kind. The kind and quality of coal, however, vary greatly with the section and even within the section in which it is mined, from the high heat value bituminous coals of the West Virginia and Pennsylvania regions to the lignites of the southwest and northwest.

The choice of the kind of coal to use will depend on the available supply, the heat value and the distance it must be transported. For the stations that are nearer the mines and where the freight charge is not such a great proportion of the total cost, the lower and cheaper grades of fuel will often be the most economical in spite of the decreased efficiency. For the more remote stations, however, the freight charge becomes the greater part of the cost and therefore it will be more advantageous to use a higher heat value coal with its better efficiency of combustion. This is particularly true of the New England States which have no developed fuel supply within their own limits and for whose use coal must be transported over long distances. Here only the better grades of bituminous coal from West Virginia or Pennsylvania are used.

The equipment for burning the coal varies in type with the grade to be used. For the high grade bituminous coals or coals of the coking type, the underfeed type of stoker is used. These stokers permit of burning continuously large amounts of coal per

hour per square foot of grate, and in conjunction with the forced draft which is required, enable the boilers to be operated at high ratings. They are flexible in their operation, permitting the operation of the boilers to follow closely the fluctuations in the load. They consume little coal when banked and can be brought up from a banked condition and put on the line in a very short time. In recent large installations the lengths of the stokers have been increased and clinker grinders substituted for the usual dump plates. These features, together with the addition of auxiliary blast ducts admitting air to the back of the stoker, permit the practically complete combustion of the fuel, thus greatly decreasing the combustible in the ash and adding to the efficiency of the plant.

For the lower grade coals, with high ash content, high volatility, and usually a high percentage of sulphur, chain grate stokers have been used. The earlier types of these stokers were natural draft, but the demand for higher ratings has led to the rapid development of traveling grates using forced draft. The Coxe stoker is of this type and has been used successfully for a number of years, principally in the anthracite region. It has proved equally successful when burning the semi-bituminous and lignite coals of the Middle and Far West. Other makes of forced draft chain grate stokers are being developed and recent installations indicate their success in meeting the operating requirements of the installation. The underfeed stoker has also invaded the semi-bituminous and lignite field with some fair success. The most success seems to have been obtained with stokers having some positive ram action to help the feed of the coal down the grate and to break up any heavy clinker that may form on the grate.

Anthracite coal has usually been used for domestic purposes. The smaller sizes, such as barley and buckwheat, are available for making steam, and the forced draft chain grate has also made usable the vast culm banks thrown aside in former years as unfit for use. Fine coal from the washeries deposited in the beds of creeks and rivers in the anthracite regions is being dredged out in great quantities and reclaimed for use as fuel. This great supply of anthracite, unfit for domestic use, but capable of being burned under boilers, has developed a market for itself and is being used in localities well outside the anthracite field. Existing installations have demonstrated the ability of the forced draft chain grate to burn these types of fuel with sufficient grate speed and combus-

tion rate to develop boiler ratings of well over 200 per cent. continuously. Before making any decision to use this fuel outside the anthracite field, a careful comparison should be made of the efficiencies as compared with other and better grades of fuel that may be available. The source of the supply and its continuity should be well established. Dredging for river bed coal is interfered with during cold weather and larger reserve stocks will have to be carried at the plant to insure continuity of service. And lastly, in order to make sure against possibility of loss, the cost of the additional installation for anthracite burning equipment should be considered as written off during the life of the anthracite contract. This puts the burden of proof heavily up to the anthracite coal man, but it is the only safe method where the type of fuel is special and inability to renew a contract for any cause will mean radical changes in equipment.

Pulverized Coal.

Pulverized coal has been attracting a great deal of attention lately and several installations are now in successful commercial operation. The preparation of pulverized coal has been pretty thoroughly worked out through its use in the cement industry, but its combustion under boilers is of comparatively recent development. The earlier installations were made under existing boilers whose settings were not designed for pulverized coal, and limitations were thus imposed which precluded the best operating conditions and results being obtained. Several installations designed and proportioned for the burning of pulverized coal are being built and put into operation that give promise of successful and economical operation. Tests are now being conducted on a modern boiler installation at Rivermines, Missouri, and a complete new power station of 40,000 kw. initial installation, using pulverized coal, was placed in commercial operation at Milwaukee on December 23, 1920. These should furnish interesting and valuable data on the subject and have an important bearing on the future of the system.

The principal field for pulverized coal lies in the low-grade coals that can, with great difficulty, if at all, be burned on existing stoker equipment. Whether or not the small increase in efficiency in burning the better grades of coal in pulverized form is warranted, depends upon the size of the installation and the load factor.

Oil.

Oil has been used for fuel in some localities for a number of years. These have been principally in the oil fields or in places where there was cheap water transportation as compared with high freight rates on relatively poor coal. The older installations used steam atomizing burners operating on natural draft. Difficulties in properly mixing of oil and air produced a long flame and required so much combustion space that the amount of oil it was possible to burn under a boiler limited its rating to around 200 per cent. From two to three per cent. of the steam generated is required for atomization.

The mechanical atomizing oil burner has been used for some time on shipboard, but only within the past eighteen months has it been adapted to land service. With this type of burner, using forced draft, it has been possible to burn 1300 lb. of oil per hour in one burner. The proper proportioning and mixing of oil and air in the burner requires less combustion space than with steam atomization and permits operating the boiler at higher ratings and with but slight drop in efficiency at the higher ratings.

There have been a number of recent installations of oil-burning equipment in stations along the Atlantic coast, extending as far north as the New England States. These installations have been made possible economically by the high price and scarcity of coal, and by the number of new refineries erected for the production of gasolene by the "topping process." This process leaves an oil of around 18,000 B.t.u. per pound which is available for burning under boilers. It has been a case of the "early bird getting the worm," for later installations that were contemplated have not been made because of the inability to obtain oil at a price that will compare with coal or under a contract for any length of time or that will guarantee a reliable supply.

Comparison of Coal and Oil.

In making a comparison of the relative economy of oil and coal the same remarks apply as for anthracite coal; that is, in the cost of the oil must be figured the charges necessary to wipe out the investment for oil-burning and storage equipment and of

changing back to coal at the end of the contract. These are proper charges against the use of oil and must be made if the comparison is to be complete. At the end of the contract this method leaves one free, either to undertake a second contract at a higher price, if the price of coal has not increased, or to effect a larger saving if the price of oil has not gone up.

II. MECHANICAL FEATURES OF DESIGN.

The design of the power station structure and the arrangement of equipment do not in themselves have much direct effect on station economy, although they do have an important influence on the amount of labor required for operation and on the cost of maintenance.

There are more ways than one to solve the problem and local conditions often play such an important part that to attempt to generalize and say that one type of arrangement is better than another, especially without all the facts, would only invite controversy without hope of agreement. There are certain facts and principles, however, applying to the general subject which can be stated without risk of an argument.

Divisions and General Arrangement of Plant.

The arrangement of a steam power station naturally divides itself into three parts:

1. The boilerroom or that portion in which is located the equipment to produce steam,
2. The turbine room or that portion in which the steam is used to produce electrical energy, and
3. The electrical bay or switch house, being that portion in which the electrical energy is received from the generator, and distributed to the feeders going to different parts of the system.

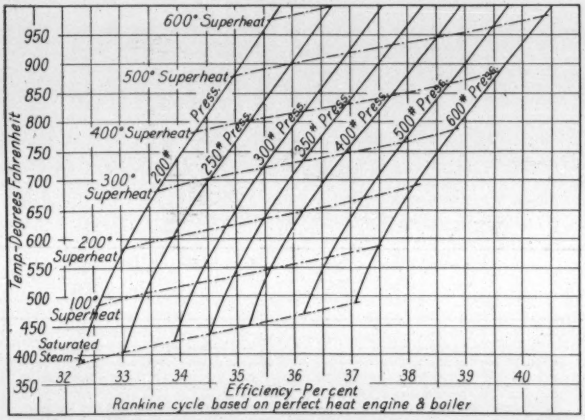
For simplicity of operation and arrangement the three parts usually are placed side by side with the turbine room in the middle. Ordinarily only one division wall separates the boiler and turbine rooms. The electrical bay is sometimes placed with a single division wall between it and the turbine room, and sometimes in a separate building or switch house. There are a few instances where the electrical bay is at the end of the turbine room

and some where the switching equipment is above the turbine room. Local conditions and other special reasons have usually dictated these arrangements.

Operating Floors.

Each portion of the plant will have different operating levels or floors (Fig. 2). Thus in the boiler room we have the ash room, boiler floor and sometimes the economizer floor levels. In the turbine room, the condenser floor and turbine floor or plat-

FIG. 1.

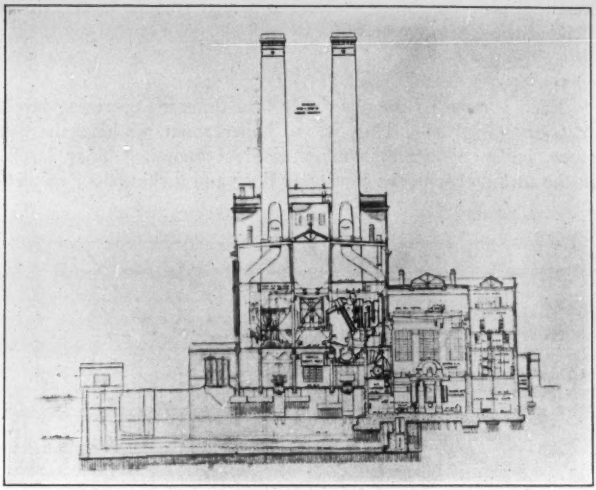


Theoretical efficiencies of Rankine Cycle computed from Temperature-Entropy diagrams.

form, and in the electrical bay, we have reactor floor, bus floor, switch floor levels, etc.

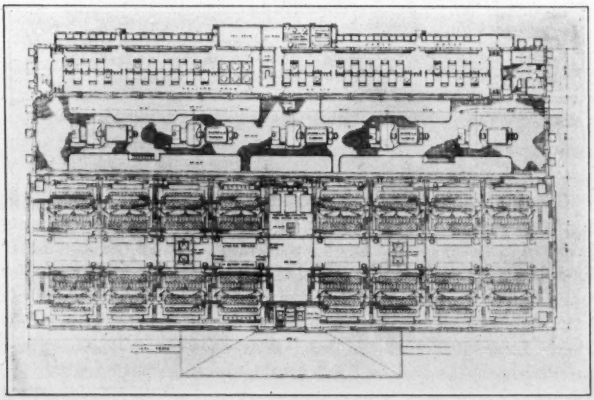
The number of floors or operating levels in a plant should be kept to a minimum, and as far as possible the different operating levels of adjacent portions be the same. Thus the condenser floor and ash room floor levels should be the same and the boiler room and turbine floor or platform. Local conditions sometimes make this possible, as for instance, in stations located on streams where great differences in level between high and low water are encountered and where condenser pumps must be placed so as to operate at low water. This occurs in some places in New England

FIG. 2.



Cross section—South Meadow Station. The Hartford Electric Light Company.

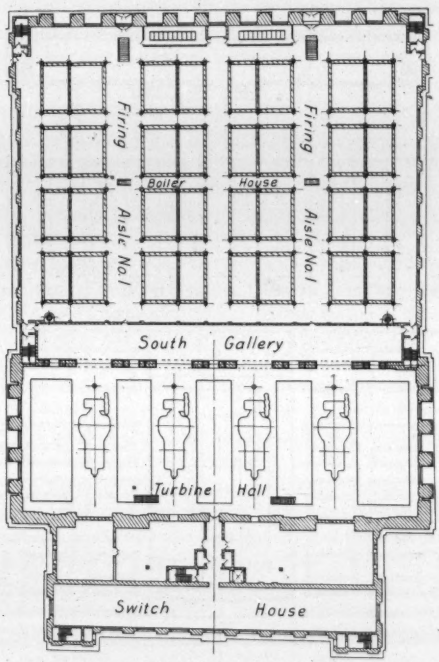
FIG. 3.



Plan—Boiler room and turbine platform, South Meadow Station. The Hartford Electric Light Company.

where there are differences in water level of 30 feet (Fig. 2), and in the Middle West where differences in level vary from about 30 feet around Pittsburgh to 65 feet at Cincinnati. These conditions create special and difficult problems in arrangement of

FIG. 4.



Plan—Chester Station. The Philadelphia Electric Company.

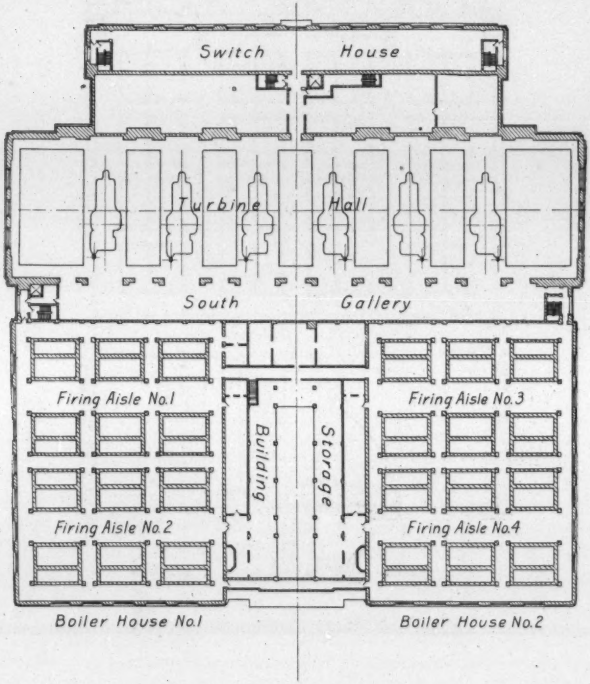
equipment and design of foundations, they cost more to erect and force a compromise with more desirable arrangements.

Turbine Room Arrangement.

Turbine units are arranged with their shafts either lengthwise (Fig. 3) with or crosswise (Figs. 4 and 5) to the turbine room.

When arranged lengthwise they are usually placed in a single row, although the two-row arrangement has been used in several stations, having been first done to permit of the installation of a maximum of capacity in a station originally designed for smaller vertical units.

FIG. 5.



Plan—Delaware Station. The Philadelphia Electric Company.

Boiler Room Arrangement.

Arrangement of the boiler room is usually along one of two lines, either with the firing aisles parallel with (Fig. 3) or at right angles to the turbine room (Fig. 4).

The right angle boiler room is ordinarily used in a station arranged on a unit system, that is, when each unit has its own boilers and auxiliaries complete.

This arrangement divides the boiler room into a number of different firing aisles, usually half as many as there are main units. Each aisle has its complete installation of coal and ash handling equipment and each row of boilers has its ducts, flues, chimneys, etc., distinct from the other rows. The arrangement splits the boiler room operation into as many sections as there are aisles.

In the parallel boiler room (Fig. 3) the boilers are in rows parallel with the turbine room, with usually only one firing aisle, unless the boilers are double stokered. This arrangement utilizes the same coal and ash handling system for all the boilers and does not split the operation into separate groups. On the other hand, it makes a longer boiler room, which usually extends beyond the ends of the turbine room unless the turbines are placed lengthwise, or if crosswise, are spaced farther apart than actually required.

A compromise between the two is employed in the new Delaware Station of The Philadelphia Electric Company (Fig. 5) in which there are four rows of six boilers each, with two firing aisles parallel with the turbine room. This gives four boilers in a line at right angles to the turbine room. The piping is so arranged that each line of four boilers ordinarily serves one unit, which is placed with its shaft crosswise to the turbine room.

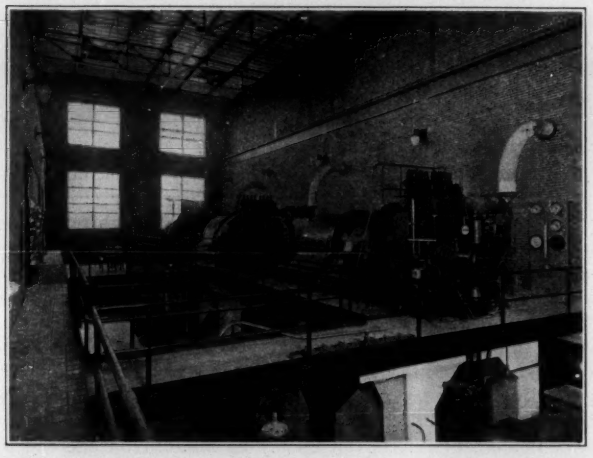
As far as ground area occupied is concerned, there is not much difference between the two arrangements, what there is, however, generally slightly favoring the parallel arrangement. Boilers are usually fired from one end only, as enough grate area and a sufficient number of retorts can usually be installed on one end to develop continuously ratings of over 200 per cent. In a few cases, however, boilers are fired from both ends. This is the case at Detroit where the boilers are of such large nominal rating that sufficient grate area cannot be installed at one end and therefore it is necessary to stoker from both ends to obtain even the moderate ratings at which these boilers are run. In other stations such as at Buffalo, and in the Springdale Station of the West Penn Power Company, where very high ratings are carried continuously, it is necessary to fire from both ends.

Heights between floors and different operating levels should be ample to allow the installation of the equipment without crowding, and headroom for proper operation (Fig. 2).

Lighting.

Sufficiency of light, both natural and artificial, and accessibility of equipment are factors that help toward proper operation and lower maintenance, and should be given careful consideration. To this end it is becoming more and more general practice to make the turbine room floor of area sufficient only for the proper operation of the equipment located thereon and leaving the rest

FIG. 6.



Pittsburgh Plate Glass Company, Kokomo, Ind. Turbine room, looking southwest.

of the space open to the condenser floor (Fig. 3). This permits natural light to reach all parts of the condenser floor and allows the use of the turbine room crane for dismantling and erecting most of the auxiliary equipment (Figs. 6 and 7).

Accessibility.

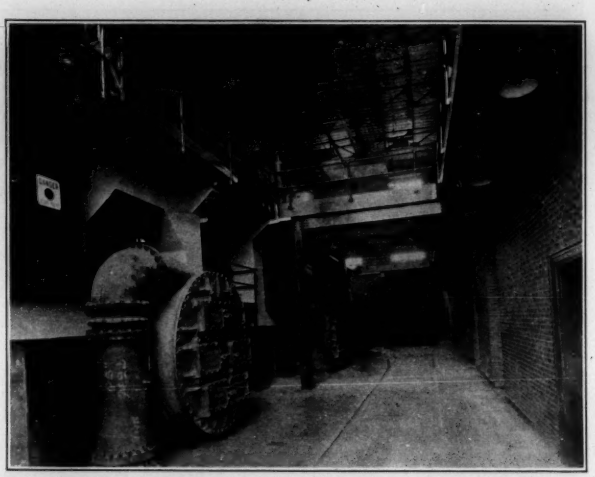
Providing easy access to various equipment and parts of equipment by means of stairways and walkways are an aid to operation, especially in the boiler room. Combination passenger and freight elevators are frequently installed in the boiler room and electrical bay. The height of a modern power station is frequently more

than that of a six-story building, so that these provisions are not in the nature of a luxury but are a real necessity.

Framework.

Most stations have a steel framework with brick walls and concrete floors, either plain or covered with tile. This is generally considered the best combination from the standpoint of rapid and economical construction, ease in hanging and erecting piping

FIG. 7.



Pittsburgh Plate Glass Company, Kokomo, Ind. Condenser room, looking northwest.

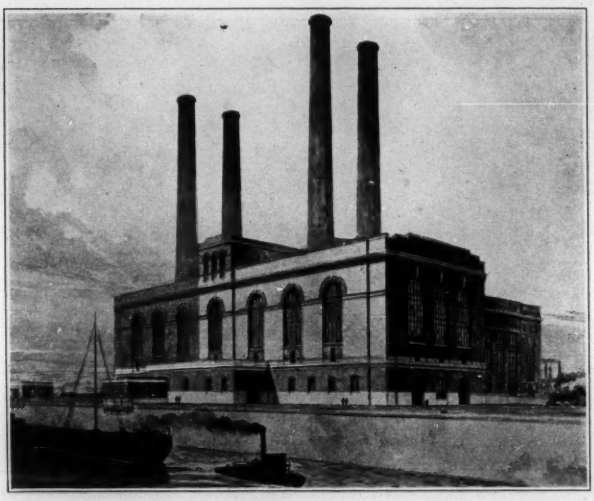
and in making changes in, and additions to, the structure. There are cases, however, where the reinforced concrete type of building has been used with economy and satisfaction, as in the northwest, where lumber and cement are plentiful and steel has to be transported across the country. The newest station of your local company has been built of reinforced concrete for a special reason. The building laws of your city require the fireproofing of all steel members of the building structure. This means encasing all beams and columns in concrete. Also the station was designed

and construction started during the war when steel could be had only with great difficulty. These circumstances led to the adoption of the reinforced concrete building and the design, as worked out by the engineers and architect, has been well adapted to its purpose.

Architectural Treatment.

The extent to which architectural design and embellishment

FIG. 8.



General elevation—South Meadow Station. The Hartford Electric Light Company.

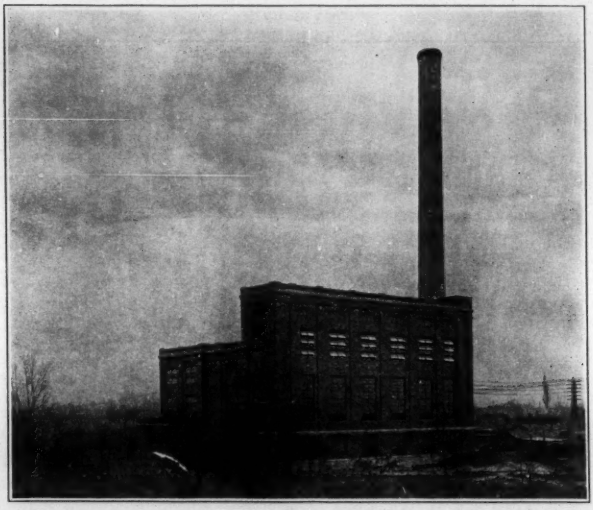
should be carried will depend on the character of the neighborhood in which the station is located and the value which is placed on appearance as a matter of public policy or as an aid to obtaining business and in promoting cleanliness.

A station built in a locality of a better sort requires treatment that will not detract from the surroundings. Its appearance should also be such as to impress a prospective large user of power with its stability and convince him that the service he will get will be

absolutely reliable. On the other hand, there is the danger to be avoided that he will consider the station too ornate and that an undue portion of the money he will pay for power will go to meet fixed charges on unwarranted investment. With careful study, however, a simple and adequate treatment can be worked out (Figs. 8 and 9).

In regard to the interior treatment, these same remarks apply.

FIG. 9.



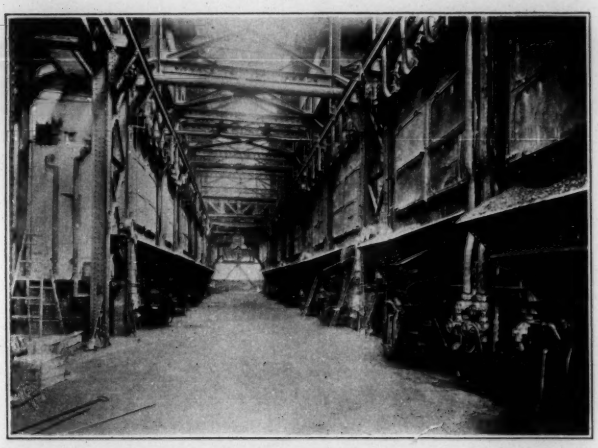
Pittsburgh Plate Glass Company, Kokomo, Ind. Power station, looking southeast.

Here, however, is involved the question of neatness and light as an aid to cleanliness and maintenance. In the turbine room, light-colored walls aid the light in reaching remote places where dirt might be allowed to collect or where equipment is located that might be neglected if the place were dark. Whether enamelled, or other light-colored brick be used or the walls be painted, will depend on the relative cost and the value placed on this feature. Painted walls require being done over every few years; brick walls

require cleaning down at regular intervals to give maximum effect.

A double or suspended ceiling improves the looks of the turbine room but is not usually justified for this reason alone. It does, however, provide an air space between the roof and the turbine room and with proper ventilation is a great aid in preventing roof condensation in winter. This has been a great source of trouble, especially in the older stations, and much study is being given to the subject. The elimination of the causes of moisture, such as

FIG. 10.



New Bedford Gas and Edison Light Company. Boiler room, looking east.

steam seals exhausting into the room, leaky joints and open blows, will do as much toward diminishing this trouble as anything else. Gypsum is being used more and more for roofs with a view toward decreasing condensation.

Floors are usually of tile or cement finish, treated with some form of hardener to prevent dust and wear. Tile is often used in the turbine room and condenser floor. It is easy to keep clean, adds to the appearance of the room, and its cost is not prohibitive.

In the boiler room the equipment and the operations are of

such nature as to make any architectural treatment difficult and unnecessary. Care should be exercised in the design, however, to reduce to a minimum places where dirt can collect. I refer to spaces in and around columns, gusset plates projecting above floors, ledges and other places where articles, such as waste, can be carelessly left or thrown. A little study during the period of design can usually greatly reduce the number of these places without increase in cost of construction.

Design of structure should be such that maintenance is not only possible but easy. Exposed structural and other steelwork should be accessible for repainting and steelwork in damp or wet places such as the ash room should be protected from corrosive action.

Light in the boiler room is as important as in the turbine room. Windows should be ample and properly placed to give light where it is needed. Care should be taken not to overdo, however, as windows to be effective require cleaning, and fewer windows properly cleaned are as effective as many more that are not kept clean. The use of skylights over the boiler aisles, along the sides of the coal bunker if it is over the aisles, or if the bunker be central, over the whole aisle, aids in getting light over the boilers and along the aisles (Fig. 10).

Stacks and Flues.

In large modern stations, stacks are usually superimposed on steelwork above the boilers to save the space in the building that would be required to run them down to foundations on the ground. At first all the superimposed stacks were of steel, but of late concrete stacks are being built superimposed. The concrete stack weighs somewhat more than a steel stack, but it has to be lined only a small proportion of its height and requires practically no maintenance while steel stacks require painting every two to three years.

Flues are now usually placed on the roof of the boiler room to reduce headroom over the boilers.

Ventilation and Heating.

Ventilation and heating of the station are being given more careful thought with each new design. Buses, reactors, transformers and electrical switching equipment give off considerable

heat. They are usually located in rooms closed from the outside air and require artificial ventilation to provide a constant circulation of air to remove the heat generated. The air for this purpose is usually washed to remove dust and dirt and to cool it in summer. In winter the air is usually tempered after washing to prevent the rooms from becoming excessively cold. Circulation is usually by forced draft or exhaust fans, or both.

Turbine room ventilation is often combined with the generator air washing and cooling system. In this case the washers usually draw air from the room. In the summer time with the doors and windows open this draws the outside air into the turbine room and into the generator cooling system. The heated air is either discharged outside the building, into the ash room where the forced draft fans can take it, or in the older units out of the top of the generator, whence it rises toward the roof and out through ventilators or louvres. In the winter time the air is usually discharged into the turbine room to help keep the place warm. In one station all the air is washed before coming into the turbine room and the generators draw air direct from the room and discharge into a mezzanine floor over the ash room, where it is taken by the forced draft fans.

The ventilation and heating of the turbine room has a direct bearing on the amount of roof condensation that will occur in winter. In one station now under construction, after careful study, a system was worked out and is being installed, which it is expected will prevent roof condensation. The roof trusses are arranged for a suspended ceiling, and by a system of ventilators there will be a circulation of air between the ceiling and the roof. The generator air washers are used in the scheme about as previously described, and in addition a separate fan will deliver sufficient washed and warmed air into the room to produce at all times a slight positive pressure in the turbine room. What air leakage there is will therefore be outwards and no cold air will be drawn into the room.

In the boiler room the air required for combustion is many times that which may be discharged by the generators into the room, and in practically all stations this air is drawn from the boiler room and ash room. The amount is sufficient to change the air in these rooms many times an hour, making a very cold

place in winter time and exposing pipes to danger from freezing. This condition should be given serious study in new stations with a view to providing means for taking this air from the outside in the winter time.

The boiler room should be closed from the turbine room, both as an aid to keeping the turbine room warm in winter and to prevent dust and dirt from getting into the turbine room. Cleanliness can be promoted by closing in the coal bunker from the remainder of the boiler room to prevent coal dust raised while filling the bunker from permeating into other parts of the building.

Coal and Ash Handling.

The handling of coal and ashes is usually a special problem. Methods of unloading, storing and conveying depend on the way coal is received at the station, the size of the plant and the amount stored. The amount stored depends on the plant output, load factor, the distance from the coal supply and the space available. Elaborate handling and storage systems are expensive and warranted only in large installations. Some of the largest stations store and reclaim all their coal by means of locomotive cranes. This method has great flexibility and requires less expensive equipment, but is slower and consequently takes more labor than a complete automatic equipment. In the large stations located on salt water, coal is usually unloaded directly from barges into storage or into the power station bunkers. The two largest stations in Boston have ground adjacent to them for coal storage and fairly elaborate storage and reclaiming systems are installed. In New York where real estate adjacent to the station is not available and in the two new stations of your local company, coal is conveyed directly into the station bunkers. This requires bunkers of larger capacity than with outside storage or storage of coal remote from the station.

Overhead storage in bunkers is either provided over the boiler aisles with individual spouts to the stoker hoppers, or the bunker is located at the ends or centres of the aisles and coal taken from it and conveyed to the stoker hoppers by traveling larries. Sometimes larries are used instead of the individual spouts when the bunkers are over the aisles. The larry is coming more and more into general use. It has the advantage of making the whole

storage space available for any one boiler instead of only the portion immediately over it as in the case of individual spouts. It keeps the boiler aisle free from spouts and chutes which have to be removed when it is desired to open the doors on the boiler fronts for inspection and cleaning. It is a reliable piece of equipment and danger of shutdown due to accident is remote. In the larger stations, two or more larries are provided, and danger of shutdown is eliminated.

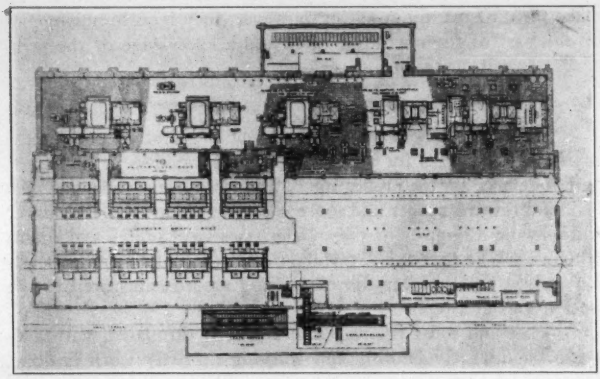
Close record should be kept of the coal consumed and for this reason it should be weighed as it is used. In some stations coal is weighed as it is being conveyed to the bunkers and a check on the station consumption made at intervals of a week or a month. To do this it is necessary to estimate the amount in the bunkers at the end of each interval. This gives a quite accurate measurement over a period of time, an error in one measurement being compensated for at the next. This method does not, however, give the close and detail check that is given when the coal is weighed as it is fed to the stoker hopper. This can best be given by the weigh larry, or by individual automatic scales placed in the downspouts to the stoker hoppers where this method of feed is used. The detail check on the coal burned is of great value in indicating the hour-to-hour or day-to-day performance of the boilers and shows up inefficient operation in time to correct it immediately. It also has a psychological effect on the boiler room labor who are more liable to realize the importance of careful operation when they see so much stress placed on the accurate accounting for the coal used. It shows the coal burned by each shift and properly worked a friendly spirit of rivalry can be engendered that will work toward improving the station economy.

A simple laboratory for the testing of fuel used and of samples of feed water is usually warranted in the larger stations. This affords means of quickly, accurately, and frequently checking up these important items of operation.

The handling of ashes is always a nasty and vexing problem that is seldom satisfactorily solved. In the large stations where the facilities permit it, ashes are being dumped from the hoppers direct into railroad cars. This is a very satisfactory and wholesale way of handling the problem. In the smaller stations a motor

truck serves the same purpose. In order not to require too frequent dumping, hoppers should have capacity enough to hold a day's accumulation of ashes. They are usually directly over the ash tracks. In stations where facilities do not permit of handling in this manner, industrial railway cars drawn by storage battery or gasolene locomotives are usually employed. These take the ashes out of the building where they are disposed of on the lot, or elevated into overhead bunkers to be drawn off into railroad cars, trucks, or barges.

FIG. 11.



Plan—Condenser and ash room floor, South Meadow Station. The Hartford Electric Light Company.

Importance of Simplicity in Arrangement.

Simplicity of arrangement is an important aid to good operation. Auxiliaries for one main unit should be arranged similar to those of other units (Fig. 11). Piping systems, both steam and water, should be as simple as it is possible to make them and still properly perform their intended functions. Duplication of lines to minimize chances of shutdown often defeats its purpose through too great complication. Careful study in the design of a simple system, with proper number and location of valves, can often accomplish as much toward safeguarding operation as a great duplication of systems. Piping, after making due allowance for

flexibility and expansion, should be as direct as possible, with lines and valves similarly placed for similar pieces of equipment.

Automatic Regulation.

Devices for the automatic regulation of various equipment and phases of operation are being more and more employed. They vary the operations of auxiliary equipment, the rate of supply of fuel and water, and the conditions of draft in accordance with the load. They aid in decreasing the operating cost by practically eliminating manual manipulation, and by adjusting the conditions to the load more closely than is possible with hand regulation. To make them of maximum effect, however, they require intelligence on the part of the operating force and a knowledge of the principles of their operation.

Conveniences for Operating Force.

Provision of offices and places for the preparation and storage of records, facilities for the comfort and cleanliness of employes, and of devices for the prevention of accident to equipment and men is an aid toward proper and more efficient operation. The larger stations and a number of the smaller ones have offices and rooms both in the boiler room and turbine room, where the men in operating charge can go over the charts and records and prepare the station logs and reports.

Locker and toilet rooms, clean and well ventilated, with adequate facilities for bathing and washing up after work is done, are essential parts of a modern station. Promoting cleanliness in person aids in the maintenance of general cleanliness, and in securing and keeping a desirable class of labor. Many large stations now have restaurants connected with them where employes can obtain hot food and drink for their meals.

Accident Prevention.

Attention should be given to providing against accident to men and equipment. Guards should be placed around gears and chains, belts and other dangerous moving pieces of equipment. Grease cups should be brought out where they can be reached without danger. Curbs and railings should be placed around openings. In general, a careful study of the accident hazards should be made both during the design and after the installation is complete.

III. OPERATION OF PLANT.

To obtain maximum economy a steam power station should be operated practically under a condition of continuous test. To do this the performance of the various equipment, and of the plant as a whole, must be closely followed, and instruments should be installed to indicate and record the results obtained and the conditions affecting the operation.

The instruments should be of such type and in sufficient number to give indication of faulty operation and a continuous record of the results obtained.

Care should be taken that not only are all necessary instruments installed, but that unnecessary ones are omitted, as these give records that are not vital to the operation and by adding to the data obtained, tend to confuse the interpretation of the useful records. These instruments should be read at frequent and regular intervals and recorded on a station log sheet. This station log or operating record should be so arranged as to facilitate analysis of the results obtained. Related figures should be brought together to show the effect of variables under control of the station operators, such as loading, vacuum maintained, draft, flue gas temperature, boiler rating, fuel used, etc. The results should be worked up promptly at the close of each watch by members of the station force so that the men themselves may thoroughly understand the figures and profit by the comparisons shown. A report should be made up each day giving the average conditions obtaining and the results obtained, including peak load, kilowatt hours and fuel per kilowatt hour.

To maintain the desired dependability and efficiency in power station equipment, it is necessary to place such equipment under a system of definitely scheduled inspection and maintenance. By this means every piece of apparatus is thoroughly inspected at regular intervals and potential causes of trouble discovered and remedied before great damage is done. In order that maximum benefit may be derived from the experience gained in making these inspections and repairs, the records of this work should be systematically entered in a concisely indexed log book so arranged as to provide a convenient usable reference for those immediately responsible for the upkeep of the equipment.

Of almost equal importance with the actual operation and maintenance is the installation of a system of cost records. Every

month a complete report should be made up from these records, giving the operating results obtained and the station costs arranged to show clearly the cost of any phase of operation or maintenance both in total amount and on a unit basis. Only by such means can the economy and cost of operation be studied and kept within reasonable limits.

The Preparation of Sodamid and Sodium Cyanamid from Lead-Sodium Alloy.—In a thesis presented to the Technical High-school at Karlsruhe, WILLIAM LEIBROCK presents numerous data on the manufacture of important sodium products. He reviews at considerable length the many efforts that have made to secure economical and convenient electrolytic procedures for preparing sodium, the initial procedure, being as is well known, due to Davy, more than a century ago. Serious difficulties arise in the conduct of such methods on the large scale, and many patents have been taken for improvements in the apparatus and in other respects. Leibrock directed his experiments along the line originally indicated by Faraday, that of absorbing the liberated sodium in a heavier metal in the liquid form as the kathode. After many trials, success was achieved with lead which formed an alloy containing a notable proportion of sodium. For the analysis of this alloy, the investigator devised the following method:

A sample with surface carefully cleaned (3 to 15 grams according to the richness in sodium) is weighed rapidly and placed in a casserole with from two to five volumes of mercury. The formation of an amalgam begins at once, and the reaction may be hastened by gentle warming. When all the lead alloy has dissolved, the mixture is allowed to cool and then covered with water. According to the richness in sodium, the reaction will be more or less violent, and finally the whole of the sodium will have been dissolved. The mixture is heated on the water-bath until the surface of the metallic mass is smooth, which indicates the termination of the solution of the sodium. Allowing the mixture to cool, the amount of sodium hydroxide formed can be determined by titration, in the casserole without regard to the presence of the lead amalgam. The latter can be subsequently distilled by which the mercury can be recovered.

The methods for obtaining sodamid and sodium cyanamid from this sodium-lead alloy are described in the essay. Leibrock states that the sodamid prepared thus is less explosive than that prepared by the customary methods, and that, while the exact cause of the explosiveness of this compound is not clearly known, it has been pointed out that it has a marked power of dissolving metallic sodium. The sodamid prepared from lead alloy has, so far as analysis shows, only one difference from the ordinary compound. It contains less free sodium, and this may be possibly the cause of the lower explosibility. H. L.

CHARACTERISTICS OF THE ELECTRIC LOCOMOTIVE.*

BY

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THE rapid growth of the United States in population and in wealth has been made possible only through its vast network of railways. Our railways, and practically the entire inland transportation system, have grown up around the steam locomotive. To this picturesque personification of power then, we owe our national greatness. However, there have been many evidences in the last few years which indicate that our railways need more power, and a different kind of power, than the steam locomotive can supply.

The rapid growth of the country, stimulated as it was by the railways, has imposed most severe requirements on them. There has been an unceasing demand from the traffic department for more power, for larger and still larger locomotives. The steam locomotive designers have risen to the occasion magnificently, and the modern steam locomotive is so much larger and more efficient than the locomotive of thirty years ago that a comparison between them is scarcely possible. It would seem, however, that the limit to the capacity of the steam locomotive has been closely approached, if it has not already been reached; and where greater capacity is required, another type of motive power must be used. The other type of power, in the shape of the electric locomotive, is in the field prepared to take an increasing share of the load from the boilers and cylinders of the steam locomotive; to take the load where the inherent limitations of the steam locomotive make it unequal to the demands upon it or its use undesirable or impracticable.

The far-seeing railway operator is studying the subject of electrification more seriously than ever before, and he confidently looks to the electric locomotive to help him out of many difficulties. He starts with the desire for more power and with

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the idea that he will substitute the electric locomotive whose power can be made anything that is desired for the steam engine whose power is limited by the boiler it carries. While there is no question as to the ability of the electric locomotive in this respect, he finally realizes that electrification requires practically a revolution in operating methods before all of its advantages can be secured.

Many of the old ideas that have grown up around the steam locomotive will have to be modified or abandoned and new methods introduced. The length of engine divisions, ruling grades, distribution of coal and watering stations, dispatching, the tonnage and speed of trains, the design of stations and terminals, have all hinged around the steam locomotive. This revolution will not have to take place all at once—it will be rather a gradual evolution of new methods that will be worked up by the more progressive operators, as the advantages and possibilities of electrification develop before them.

Among the many features that will become evident to the operating man making a close study of the subject of electrification are the following:

1. The power that can be applied to a train is in no way limited by the size of the individual motive power unit. The electric locomotive derives its power from a central power station which may carry the entire railway load and a large industrial load at the same time. Theoretically, the locomotive can draw the maximum amount of power that can be utilized at one point in the train. Whatever may be the size or capacity of the individual motive power unit, it places no limit on the amount of power that can be controlled from one cab, since two or three, or half a dozen if need be, of these units may be coupled together and operated on the multiple unit system like a train of suburban or subway cars. A locomotive may then be an aggregation of motor trucks with a single engineer's compartment. Practically the only limit to the tractive effort that can be controlled from this one point is the strength of the drawbars. Drawbar pull, however, is not the only way in which the greater power is developed; speed accounts for fully as much, and it will soon appear that the highest economical speed for traffic movement can be met by the electric freight locomotive; this may be two or three times as great as that of the steam locomotive. This is

particularly apparent on the mountain grades where the heaviest freight trains when pulled by steam locomotives make from 7 to 10 miles per hour, while the same trains, or heavier ones pulled by electric locomotives, run from 14 to 20 miles per hour. The electric locomotive makes it possible to operate freight trains at practically any desired speed. From this it can be seen that freight trains can more closely approximate passenger train schedules and thus greatly increase the track capacity.

In passenger service it is probable that it will not be considered economical to operate trains at much higher maximum speeds than are attained with steam locomotives. However, it will be possible to operate at a more uniform speed and with fewer delays. Heavy grades can be covered at as high speed as is safe or economical, so that if desired a higher schedule speed can be maintained with the same maximum speed as at present.

2. The length of the division on the railroad will be no longer limited by the locomotive. Electric locomotives make the run daily over the entire electrified section of the Chicago, Milwaukee & St. Paul Railway, between Avery and Harlowton, a distance of 440 miles, and are repeating this trip over and over until 4000 miles or more have been covered before the locomotive goes to the shop for anything but the casual light inspection it receives at ends of runs. There is no question but that the locomotive division could be much longer than 440 miles if it were convenient or desirable to make it so. If the large ocean liners can keep their engines running for a couple of weeks without stop, and Pullman cars can run thousands of miles, there is no reason why electric locomotives cannot operate equally well, and take equally long runs. Under the conditions of operation on the Chicago, Milwaukee & St. Paul Railway, even with only two passenger trains each way per day, one locomotive has made more than 11,000 miles in a single month. With the schedule arranged to suit, this mileage might easily be from 15,000 to 20,000 miles per month. This, of course, means a great reduction in the number of locomotives required. A record for a continuous 24-hour run of 766 miles has already been reached by the passenger locomotives on this road.

3. Electrification permits radical changes in terminals, due partly to the absence of smoke, dirt and noise, and very greatly

to the use of multiple unit car equipments for the suburban traffic. The absence of the smoke and dirt results in a change in the entire character of the neighborhood surrounding the railroad and its station. The railway is free to take full advantage of its aerial rights in the construction of hotels, office buildings, warehouses, etc., over the tracks, which, with steam locomotives, must be left open. What this one feature alone means in a congested centre like the Chicago district, for instance, where there are 4500 miles of steam railroad track in operation, it needs no words to tell. Wherever the value of real estate is high, the land covered by the railroad is very valuable and its use for building purposes can be made a source of revenue to the railway, which will go far towards paying the cost of the electrification.

The absence of smoke and dirt makes it safe and desirable to enter the city in a subway, and to have the tracks on two or more levels with a corresponding increase in capacity of the station site. This in the future may, in fact, be the only possible answer for the increase in needed capacity.

The use of multiple unit equipments makes large increase in the terminal capacity, especially where it is a stub-end terminal like that at Broad Street, Philadelphia, by decreasing the number of idle movements in the terminal which are necessary with the steam locomotive but are not required at all for the electric. All of these advantages are familiar to everyone who is interested in the subject.

A considerable improvement in terminals will also be made in the handling of freight. The electric switcher lends itself to any desired arrangement of terminal and yards. It has proven its value in the great Harlem River yards of the New York, New Haven & Hartford Railway where the switchers remain in continuous service a month or more at a time with no more attention than the crew can give them.

4. The advantage in the use of the electric locomotive for long tunnels is obvious. This has been recognized for many years, and many long tunnels that were objectionable with steam locomotives have been electrified with the best of results. The Simplon Tunnel, constructed under the great mountain range between Switzerland and Italy was based wholly upon electrical operation. In fact, it would probably be impossible to operate

a tunnel 12 miles long in any other way at this time. This characteristic of the electric locomotive will undoubtedly be taken advantage of hereafter in eliminating many long and expensive mountain grades by tunnelling through the mountains. There seems to be no reason why tunnels of much greater length should not be used.

5. Electrification obviously means conservation in fuel. Just how great this conservation will be is a mooted question. Some enthusiastic electrical exponents claim it will save two-thirds of the fuel that is now used by the steam locomotive. Some steam locomotive enthusiasts, on the other hand, deny that anything approaching this saving can be effected, basing their statements on a comparison with engines of the latest design and the best practice. Undoubtedly neither is wholly right, but it cannot be disputed that the consumption of fuel is attended with every refinement continuously in a modern power house, and that this can never be hoped for when this responsibility rests upon the performance of each of the thousands of locomotive firemen on steam locomotives. Bearing this in mind, it seems certain that, on the average, an electrified railway with modern steam power houses would not use more than one-half of the fuel that would be required for the railway under steam operation.

6. Another thing electrification means which is of vastly more importance to the management is the greater effectiveness of labor. This follows from the greater capacity which can be secured from the railroad machine.

It would seem that, just as it is possible for the housewife to save herself an enormous amount of drudgery in the everyday duties of keeping house by the adoption of the innumerable electrical devices which are now offered on every hand, so it will be possible for the railway operator to improve labor conditions by the proper use of the most efficient and reliable of all modern servants—electricity.

7. Last but not least among the things which are to be mentioned as following electrification of a railroad is increased reliability of the motive power. In every case where electric power has supplanted steam, this has been inevitably attended with improvement in regularity and reliability of train movement.

What are the characteristics of the electric locomotive that make it so desirable; that fit it so admirably for railway service?

1. Its maximum tractive effort is from two to four times its normal continuous running tractive effort. This depends for the most part on the coefficient of adhesion which is used for the normal tractive effort. This may vary anywhere from 5 per cent. to 20 per cent. of the weight on drivers. Of course, where the normal tractive effort is 20 per cent. of the weight on drivers, it would be impossible to secure more than double the normal. Ordinarily a coefficient at normal tractive effort of 16⅔ per cent. will not be able to give more than 100 per cent. above normal as a maximum, but where, as is usually the case, the normal tractive effort requires only from 10 per cent. to 15 per cent. adhesion, it is possible to develop as much as three times the normal. This compares very advantageously with the steam locomotive whose maximum tractive effort or given horsepower rating is comparatively close to the normal running. It means a great deal in the operation of the locomotive; it makes it comparatively easy to start its normal train in the worst position and also to start it very quickly without jerk. Everyone knows who rides on our steam trains that a heavy passenger train is usually started with a jerk. The reason for this is simply that the steam locomotive at the head of the train must jerk it if it is to start at all, because its maximum tractive effort is so close to that required for pulling the train after it is started that it has little margin. The locomotive may be amply large to pull the train at high speeds, but it cannot start it without a heavy jerk. The electric locomotive, on the other hand, can start with a steadily increasing tractive effort until the train begins to move, and the maximum tractive effort can be maintained until full voltage is applied to the motor.

2. The capacity of the electric locomotive is limited by the heating in the motors. The necessity with an electric locomotive is to keep the temperature of the parts down, which is just the reverse of that of the steam locomotive. For this reason, the electric locomotive can easily develop considerably greater power in cold weather than in warm weather. Here, again, it is just the reverse of the steam locomotive.

3. Practically all of the wearing parts of the electric locomotive have normally a long life. Therefore, all that is needed to keep the locomotive on the road is to secure proper lubrication, keep the bolts tight, brakes adjusted, and to give an occasional inspection to insure that nothing abnormal has taken place in

the equipment. This is the secret of the great mileage which is possible with the electric locomotive; it explains why the locomotive is ready for service so large a part of the time; it is the reason that only one-half or one-third as many electric locomotives are required for a given service as would be required for steam operation; it explains why the round-houses and inspection forces can be reduced to such a small limit; why the intermediate division points are eliminated; it gives the reason for the great reliability of the electric locomotive.

The foregoing are some of the most prominent general characteristics of the electric locomotive. It must be understood, however, that there are many other characteristics, depending on the specific type of locomotive that is under consideration; in other words, on the system which is adopted for the electrification. These characteristics are apparent chiefly in the speed and tractive effort curves. The three types of locomotives which are in use in this country to-day are, first, direct-current with series wound motors; second, single-phase locomotives with commutator type motors having series characteristics; third, constant-speed locomotives fed either from a single-phase trolley by means of phase converters or from double trolleys carrying three-phase current.

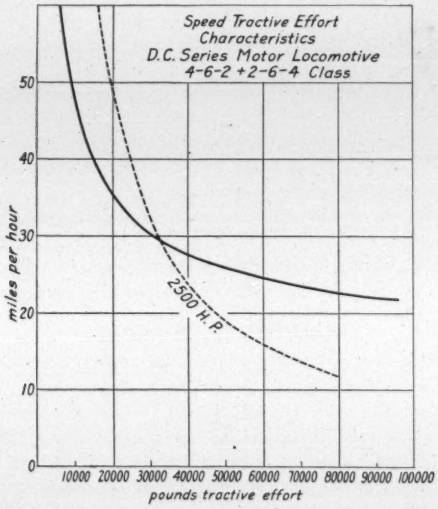
DIRECT-CURRENT LOCOMOTIVE.

The series wound motor is the one which is in practically universal service the world over where direct current is used. Its characteristics are especially suited for railway service, since the speed curve falls rapidly as the tractive effort increases, which gives the best characteristic for dividing the load, especially where a considerable number of driving units are operating in the same train. It also permits the motor to handle a much heavier load or a normal load on much heavier grade than would be possible if the speed did not fall with the increase in tractive effort.

It gives, in a way, the same effect as the shifting of gears on an automobile enables it to exert an unusual amount of effort with a relatively small engine. The method is not the same, but the result obtained is similar. The solid curve on Fig. 1 shows the performance of the direct-current series motor. Thus, it can be seen that this slowing down of the speed with increased effort relieves, to a certain extent, the whole electrical supply system—the trolley, the transmission lines, and the generating

units—from the peak loads caused by starting heavy trains or by hauling over heavy grades. When lighter grades or level track is reached, the characteristics of the series motor cause it to speed up very rapidly, as shown by the shape of the curve, so that full advantage is taken of the falling off of the load by increasing the speed. While running over a varying profile, it can be seen that the speed of the motor will vary much the same

FIG. 1.

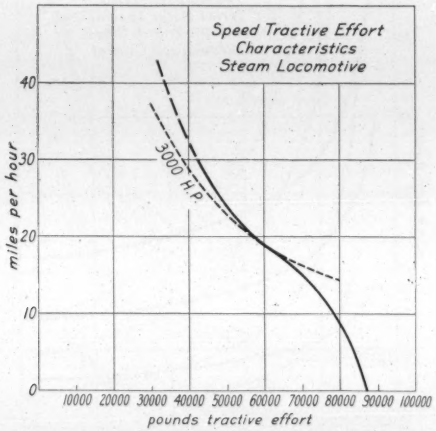


as that obtained with a steam locomotive. Speeds will be considerably reduced on heavy upgrades, but may be quite high on level track, and as high as the roadbed will permit on downgrades. A train running behind time may be pushed to the limit at every opportunity, and the time made up.

On all of the figures in dotted lines are plotted a series of constant horsepower curves. That is, the speed and tractive effort read from any point on a given curve will produce a constant horsepower. The direct-current motor curves at the higher speeds resemble these constant horsepower curves, and run very

nearly parallel to them. On Fig. 2 is plotted a curve showing the speed-tractive-effort characteristics of a modern steam locomotive. This curve has the desirable faculty of following the shape of the constant horsepower curves very closely. On the other hand, however, it does not have the same desirable characteristic at the heavier tractive efforts which is evident on the electric motor curve, namely, that of rapidly increasing its pulling power as the load increases. The torque of a steam locomotive

FIG. 2.



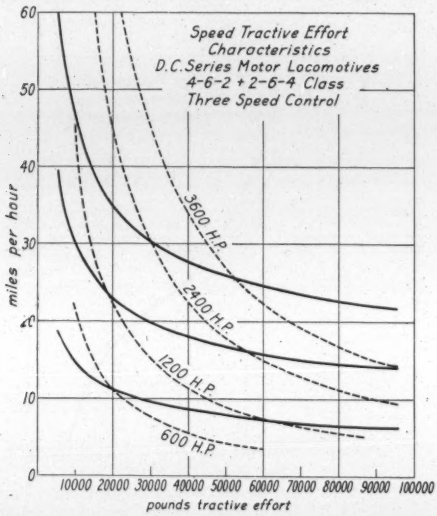
is limited definitely by the ability of the boiler to supply steam and the cylinders to utilize the steam. This is shown by the rapid falling off of the curve when this point is reached.

These curves then illustrate the advantage of the series motor characteristics which approach the constant horsepower curve over a certain portion, and at the same time permit of exerting very high tractive efforts when necessary.

With the series motor, the only means of controlling the speed is by varying the voltage on the motor. This may be accomplished by inserting resistance in series with the motor, but this is very inefficient, and cannot be used for other than acceleration. The common method used for obtaining this speed

control with direct-current motors is to connect the motors in different series and series-parallel combinations. Fig. 3 shows three speeds obtained by connecting the motors: First, all in series so as to give one-third voltage and speed; second, in series-parallel to give two-thirds voltage and speed; and third, in parallel to give full voltage and speed. This method covers the speed range fairly

FIG. 3.



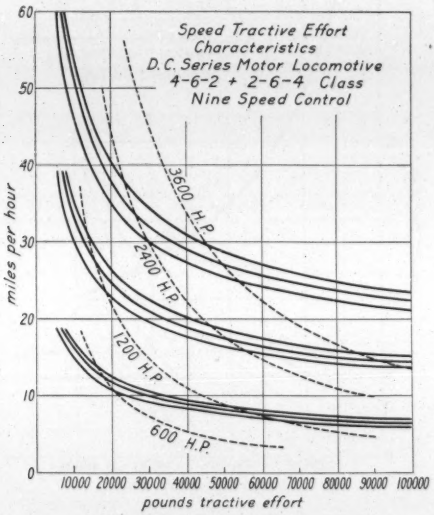
completely. Fig. 4 shows the addition of six more running speeds, making nine in all. These additional speed curves are obtained by varying the effective turns on the motor field. With the use of these "field control" points, the range in speed is very effectively covered. This set of curves shows the characteristics obtained on the new 3000-volt, direct-current passenger locomotives built for the Chicago, Milwaukee & St. Paul Railway.

ALTERNATING-CURRENT LOCOMOTIVES.

Fig. 5 shows the speed torque characteristics of an alternating-current series motor locomotive. This curve is somewhat more

steep than a direct-current series motor curve, and more nearly approaches the constant horsepower curve shown by the dotted lines on the same figure. This type of motor does not, however, have the ability to produce the very high starting torques which it is possible to obtain from the direct-current motor, because of certain commutator limitations when drawing heavy currents. On the other hand, the speed control on this motor is very easily and efficiently obtained by varying the voltage applied to the

FIG. 4.

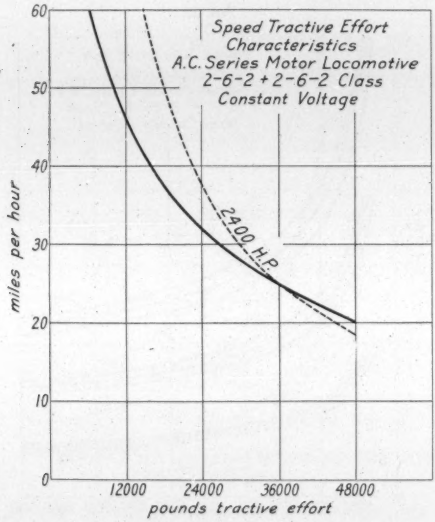


motors. Power is furnished from different taps on the transformer, and the different speeds obtained as shown on Fig. 6, without in any way altering the grouping of the motors. These curves show the speed control obtained on the latest type passenger locomotive built for the New York, New Haven & Hartford Railroad.

The other motor used for railway work is the alternating-current induction motor. This motor is essentially a constant-speed motor. Its characteristics are shown on Fig. 7 and are

quite different from either of the other two motors discussed. Other running speeds can be obtained with this motor by varying the number of poles, and by cascade connections, but it is rarely practicable to obtain more than two running speeds. The curves shown give two speeds, one at 14 miles per hour, and the other at 28 miles per hour. These speeds are as obtained on the Norfolk & Western freight locomotives. Acceleration is obtained by

FIG. 5.

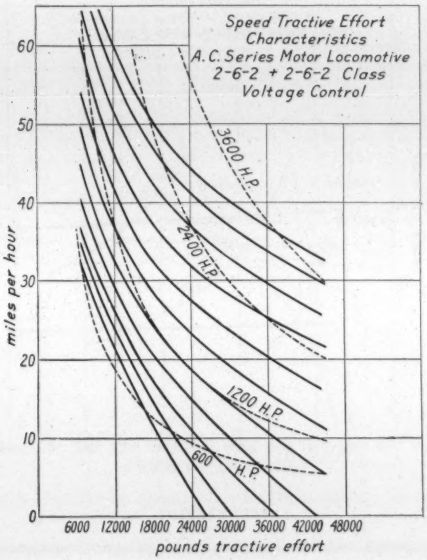


varying the resistance in the secondary of the motor, but these resistance points cannot be used as running points. This type of motor is capable of producing very heavy starting torques, and of carrying very heavy loads, but on heavy loads, the speed is maintained at practically a constant value, and the power required increases practically with the tractive effort. It is necessary, therefore, to have a motor of greater capacity than with the series motor, in order to take care of the peak loads. Some care is also necessary when operating more than one locomotive of this type in the same train, or even with different motors on the

same locomotive, to balance the load between them and not overload one motor or one locomotive with more than its proportion of load. A slight difference in wheel diameter may cause considerable overloading, unless special means are used for balancing.

There has been considerable discussion among railroad men as to the advantage and disadvantage of the constant-speed characteristic. The claim is made by some that it is a decided advantage

FIG. 6.

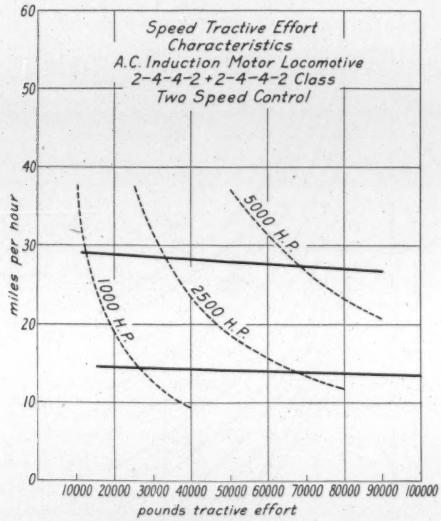


to be able to start a train from one terminal and know that, barring break-down, it will run at the same speed up hill and down, and arrive at the other terminal at a certain definite time. On the other hand, it is claimed that the ability of the series motor to take advantage of every opportunity for making speed is a very desirable characteristic, when it is necessary to make up time. A series-type locomotive of a given rating will always be

able to make a better schedule than a constant-speed locomotive of the same rating.

Fig. 8 gives a set of curves showing the characteristics of the various motors and a steam locomotive. These curves are plotted in percentages so as to be comparative.

FIG. 7.



REGENERATION.

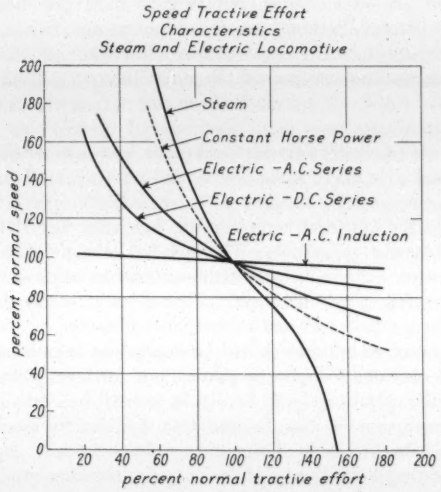
Regeneration, or regenerative braking, is another characteristic of the electric locomotive, the advantages of which cannot be overemphasized. While this feature makes it possible to reclaim some of the energy stored in a train when it reaches the top of a heavy grade and starts to go down, this saving in power does not by any means represent the full or most important benefit to be derived from it. Perhaps the most important advantage, and the one which will appeal most forcibly to the railway operating man, is the ease of control and safety provided by this

form of braking, as well as the reduction in wear on brake-shoes and tires.

Regenerative braking may be obtained on any of the three classes of locomotives previously mentioned. The methods of providing for this are, of course, different.

In the constant-speed locomotive, with induction motors, regeneration is automatic. When the locomotive, in running

FIG. 8.



down grade, reaches a speed above synchronism, the motors act as generators excited from the line. In this respect the constant-speed locomotive has a great advantage, but the speed is fixed.

The series-type of motor, whether alternating-current or direct-current requires excitation from some separate source, and therefore involves some additional apparatus on the locomotive.

Direct-current motors may be excited from a line-driven motor generator set, or an axle-driven generator; or, one or more of the main motors may be used as exciters for the others. Regenerative braking has been thoroughly tried out on the Chicago, Milwaukee & St. Paul Railway and is very successful. It permits

operation on the down grades at any desired speed and holds the train without surge or jar. The efficiency of regeneration is about the same as that of motoring.

Alternating-current series motors have been used with regenerative braking to a limited extent and various schemes are proposed for excitation. The taps on the transformer enables the speed to be controlled all the way from maximum to a standstill and in this respect it is superior to all others. Some of the schemes for excitation are very simple, but usually have the disadvantage of either limited braking power or low power factor, or both. To get the most out of regeneration will require excitation from a phase converter or one of the main motors. With that the locomotive can exert a high braking effort and will have a good power factor.

The electric locomotive is so flexible and capable of so many things that it is likely to be overloaded with all kinds of devices that are not at all essential to its operation. These add very greatly to the apparent complication, but after all do not materially affect the reliability. The trend of the times is towards simplification—the reduction of the locomotive to its lowest terms consistent with good operation. This is undoubtedly the way to get the lowest first cost and maintenance charges.

Regenerative braking should be applied on locomotives which are to be operated over heavy grades, but for level or light grade sections the advantage will hardly be worth the complication.

In conclusion, it may be said that the electric locomotive is so flexible that it can be designed to meet practically any reasonable operating conditions, while its unlimited capacity, its great mileage possibilities, its reliability, its low cost for power, and low cost of maintenance, all make it especially attractive to the railway operator.

California's Lofty Mountains. (*U. S. Geological Survey Press Bulletin No. 477*).—At least sixty mountains in California rise more than 13,000 feet above sea level, but they stand amid a wealth of mountain scenery so rich and varied that they are not considered sufficiently noteworthy to be named, according to the Geological Survey. Yet if any one of these unnamed mountain peaks were in the eastern part of the United States it would be visited annually by millions of people. But California has seventy additional mountain peaks more than 13,000 feet high that have been named, or 130 in all, as well as a dozen that rise above 14,000 feet.

SOME MECHANICAL CHARACTERISTICS OF HIGH-SPEED, HIGH-POWER LOCOMOTIVES.*

BY

A. W. GIBBS.

Chief Mechanical Engineer, Pennsylvania System, Philadelphia. Member of the Institute.

In discussing this subject it is proposed to avoid all the questions of relative economy of steam and electric operation, whether the latter be by locomotives or by multiple unit cars, for the reason that these questions have been sufficiently discussed by others who have spoken before the Institute.

With the electric locomotives there are certain questions such as the transmission of power from the motor to the driving wheels and the behavior of the complete locomotive considered as a vehicle, particularly with reference to its effects on track structure, which have not received adequate attention. These problems may best be studied with reference to approved types of steam locomotives and my remarks to-night will principally deal with the results of a comparative trial of steam and electric locomotives which was made in 1907 to secure information along this line in connection with the design of electric locomotives for the Pennsylvania Terminal in New York City. It should be understood that at that time but a limited number of types of electric locomotives were available for comparison.

It is my belief that the greatest difficulties, other than financial, of the electric locomotive are mechanical rather than electrical. None of the mechanical arrangements to be described are ideal by any means, and we must not mistake the absence of heavy repairs in the early years of an installation as truly representative of the expenses which will be met later on.

At first blush it would seem that nothing could be more ideal than the connection of a revolving armature and a revolving driving axle, there being no counter-balance disturbances as in the case of driving by reciprocating parts. As a matter of fact, it is not at all simple, for the reason that the driven axle not only revolves but is displaced bodily as well as angularly in the vertical plane.

* Presented at a meeting of the Mechanical and Engineering Section held Thursday, April 14, 1921.

Moreover, these displacements of axles and wheels, which are not spring supported, occur suddenly, due to irregularities in the track, hence it is desirable to reduce the unsprung weight to a minimum.

The difficulties from these various disturbances are encountered principally at the higher speeds and are those with which we shall mainly deal.

The different methods of communicating motion from the motor to the driving axle may be considered under the following designations:

A. The simplest method from the mechanical standpoint is that in which the armature is carried directly on the driving axle, the axle boxes sliding in vertical pedestals and the face of the field coils being parallel vertically on each side of the armature. In this construction the whole of the field coils can be rigidly secured to the frame and above the supporting springs. This arrangement permits the easy removal of the driving axles and wheels with the least disturbance of other parts. The disadvantages are the increase in the unsprung weight on the axle and the low centre of gravity of the entire motor. So far this drive has been confined to D. C. operation.

B. Next in simplicity is the geared drive, with the gear on the driving axle engaging a pinion on the motor, one end of the motor frame being carried in bearings on the axle, the other by proper nosing on the truck frame. The disadvantages of this arrangement are the low centre of gravity of the motor as a whole, the considerable unsprung weight and the gear wear, principally that of the pinion. Usually the motors are in pairs between pairs of axles, and in consequence the gyratory disturbance is less than where the motor centre coincides with that of the axle. This general type of drive, which is in common use in street car operation, is, undoubtedly, the one having the widest application and operates with both alternating and direct current.

C. The quill arrangement in which the whole motor is concentric with the axle in its normal position, but is not directly connected, the axial opening of the armature being larger than the diameter of the axle. The physical connection between quill and axle is by springs interposed between pockets in the periphery of the driving wheel centre and the arms of a revolving spider connected to the armature. These springs not only transmit the

driving torque, but also compensate for the axial disturbance of the driving axle. In some installations the motor frame as a whole is spring-supported, so as to assist in assuming a position concentric with the axle. This arrangement has been used both on cars and locomotives, including one of the cars used in the historic Berlin-Zossen high-speed trials of 1901 and 1902. The objections are the low centre of gravity of the motor, the distance between the motors measured from the centre of the truck, the fact that the motor can be removed from the axle only by drawing one of the wheels, and that any lack of concentricity between the quill and the driving axle puts a continued and varying inertia stress on the torque springs. In place of the tangential helical springs other arrangements of springs have been used, as for instance in the Zossen cars, where the springs consisted of radial quarter elliptical springs back to back, engaging pockets in the driving wheels.

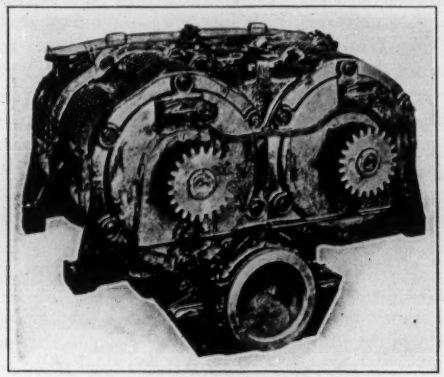
Both arrangements "A" and "C" have the further disadvantage that the ratio of the speed of the motor to that of axle is unity, thus involving higher motor weights than when this ratio is greater.

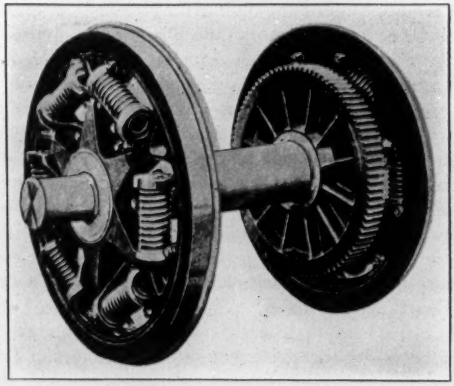
D. A modification of the quill arrangement is where the quill is driven by one or more motors through spur and pinion arrangement (Fig. 1). The advantage of this is that the motor parts are much more accessible than in the concentric type, and that the speed ratio of motor armature to driving axle may vary through a fairly wide range, and that where two motors drive the same quill the tooth load is that of a single motor. The disadvantage is the increased axle distance due to the width over two motors.

E. This group comprises the various drives by coupling rods in a somewhat similar manner to that of steam locomotives, with the exception that one revolving element is a jack-shaft driven by one or more motors and coupled by crank pins and rods to the crank pins of driving axles. The jack-shaft when placed in the horizontal plane of the driving axles maintains a fixed position relative to the driving motor or motors. The relation between them may be a second set of rods coupling the jack-shaft cranks to a similar pair on the motor; or the jack-shaft may be driven through spur or herring-bone gears cut on the periphery of the disk engaging pinions of one or more motors. These rod connections have been used more largely in Europe

than here. The jack-shaft and rod combination is an exceedingly rigid one and the wheel arrangement forms a more rigid

FIG. 1.





Quill Drive with Geared Motors.

connection than in the case of steam driving through pistons. The advantages are that the removal of driving wheels does not involve electric complications, and that all driving wheels in the

group act together, so that the full adhesion of the group is secured, and it is probable that a higher total adhesion will be available from groups than from single units where the slipping of one unit reduces the total adhesion. The disadvantages are mechanical complication involving exact quartering of all wheels and jack-shafts, the necessity of equal diameter of all driving wheels, and the heating of pins and maintenance of rod bushings. Contrary to expectation the maintenance of jack-shafts involves no great difficulty.

In no type of electric locomotive drives are there counterbalance disturbances due to counterweights, as only rotating masses are in motion.

STARTING POWER OF LOCOMOTIVES.

As governed by adhesion the motor-driven axle in starting has a relatively high adhesion because of the uniform torque of the motor. It is a well-recognized fact that static weighings of locomotives show considerable discrepancies on individual axles. How this discrepancy varies in moving locomotives is not known.

Assuming that the motor torque is greater than adhesion resistance, we have, where axles are individually driven, the adhesion of the axle with the lightest loading governing the adhesion of the group. Where, on the other hand, there is a rod connection between the various axles, we utilize the full adhesion of the group. The presence of the coupling rods does not preclude the application of power to any axle or number of axles, though the usual practice has been to apply all the power to one or more jack-shafts and from them to a group of axles. This utilization of the full adhesion in starting is a matter of importance in any type of locomotive, as usually they will pull heavier trains than they will start.

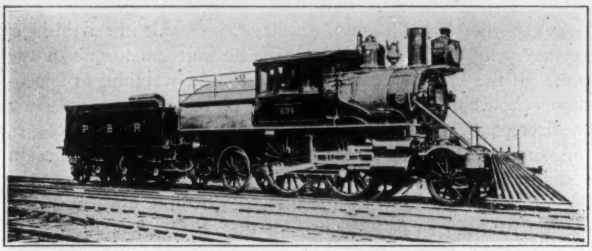
STABILITY OF LOCOMOTIVES.

In the earlier days of steam locomotives the aim was to keep the vertical centre of gravity low with the idea that this was conducive to stability. Not until the Reading Railroad in its introduction of the wide firebox type of locomotive was forced to elevate the boiler so that the firebox would clear the driving wheels, was it recognized that this change had materially improved the steadiness of the locomotive as a vehicle. The reason,

of course, was that the centre of gravity of the parts above the springs acting as an inverted pendulum failed to respond to the many small disturbances which would otherwise have produced side shocks. Since that time designers have not hesitated to raise the centre of gravity of the parts above the springs, and the present limits are chiefly those of overhead clearance.

One other steam locomotive lesson that seems to have been forgotten was that with a short symmetrical wheel arrangement with heavy overhanging weights distributed longitudinally of the whole machine, excessive lateral oscillations were set up which endangered the track and locomotive. Figs. 2 and 3 show loco-

FIG. 2.



Columbian Type (2-4-2) Locomotive.

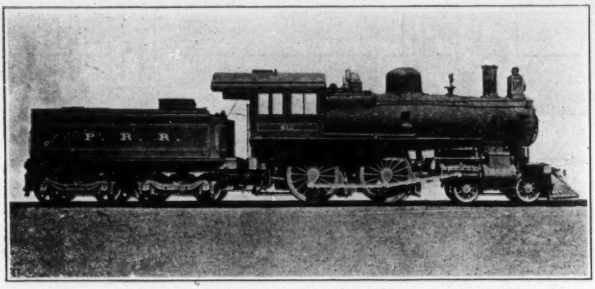
motives of the Columbian or 2-4-2 type and the American or 4-4-0 type. Here are two types of almost the same total wheel-base with nearly the same height of boiler above rail. The weight of the 4-4-0 type was but 7 per cent. greater than that of the 2-4-2 type. The 2-4-2 type was so unstable that it was soon condemned. The 4-4-0 type is notably a steady-running one and its performance will be graphically shown later. The reason for the difference in performance is probably that the wheel arrangement of the 2-4-2 was symmetrical, while that of the other was not.

In the Berlin-Zossen trials the electric cars were carried on two six-wheel trucks the outside axles of each truck being motor-driven by the quill drive. In the original construction the wheel-base of each truck was approximately 12 feet 6 inches, and the trucks were spaced about 48 feet 10 inches, the total length of the vehicle being a little over 72 feet. The road was what would

be considered light as to rail and ballast. When speeds above 90 miles per hour were reached the track began to go to pieces and had to be rebuilt. The construction of the rebuilt track, especially the very elaborate lateral bracing, indicates the severe effect of the lateral shocks in the original trials. The trucks were also rebuilt, the wheel-base being lengthened to 16 feet 5 inches. With the rebuilt roadway and car, speeds up to 125 miles per hour were reached with impunity. This is, so far as known, the highest speed attained by any wheeled vehicle.

The single-unit car does not meet the requirements of passenger transportation as we see it in this country, and the develop-

FIG. 3.



American Type (4-4-0) Locomotive.

ment of electric operation has followed two lines, *viz.*, the substitution of electric for steam locomotives for through service and the use of multiple-unit trains for suburban work. With the latter we will not deal.

When it became necessary to design locomotives to operate the New York terminal of the Pennsylvania Railroad two electric locomotives were designed and built.

Both consisted of two four-wheel trucks with motors for each axle. In both cases the trucks were articulated at the centre and carried the necessary draft gear at the ends, thus the pull was transmitted through the frames of the trucks and not through the superstructure.

In one of these locomotives the motor drive was by gear,

the second method referred to. The other was driven by four concentric motors through quills.

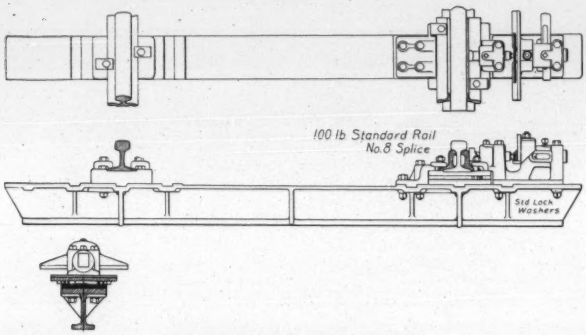
The wheel-base of both were identical, that of the trucks 8 feet 6 inches and the total 26 feet 1 inch.

Both operated by direct-current at 650 volts through third rail.

About the time that they were completed reports of troubles elsewhere made it very desirable that we should ascertain their performance before constructing the large number of locomotives necessary for the operation of the tunnels.

The line of the West Jersey was available for track and current, and it was decided to construct an experimental track with

FIG. 4.



Assembled Recording Tie.

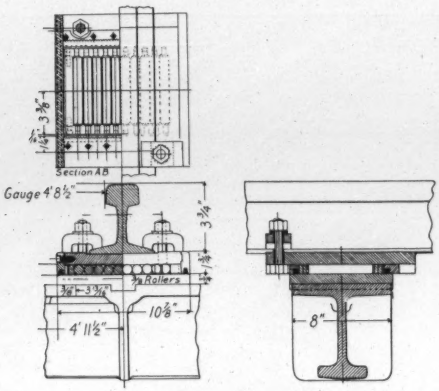
ties which would make some permanent record of the lateral impacts of the locomotives. As it was expected that the bad oscillations would occur on curves, if anywhere, only one end of the tie was arranged to register.

Figs. 4 and 5 show these ties, the end at the outer rail being so constructed that the rail was free laterally, resting on rollers, resisted against outward movement by a bracket carrying a strip of boiler plate, movable longitudinally at will. Against this strip rested a one-inch steel ball which in turn bedded in a plunger bearing against the outside face of rail. (Fig. 6 shows the test track arranged to record at each end, as referred to later; Fig. 7 shows one of the impression plates carrying the record of 30 runs.)

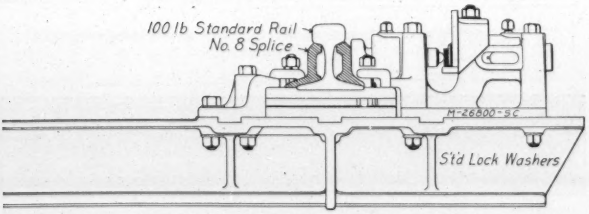
The record obtained with this device was a species of glorified

Brinell tests, the depth of the impressions of the one-inch ball in the boiler plate being taken as a measure of the impact. After each run the plates were slipped longitudinally and adjusted to touch the ball, each single plate taking the record of 30 or more runs. It is to be clearly understood that this method carries

FIG. 5.



Recording End of Tie.

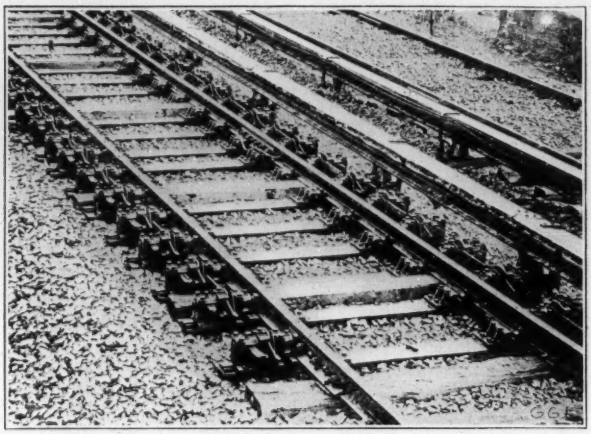


Recording Tie Showing Ball and Boiler Plate Strip.

with it some decided limitations which must not be overlooked. Each run, whether with one or more vehicles, made a single impression on each plate. While it was assumed that the indentation was that of the heaviest impact, it is possible that two or more impacts occurred on a single point with some cumulative effect. In some of the runs it is believed that this was the case.

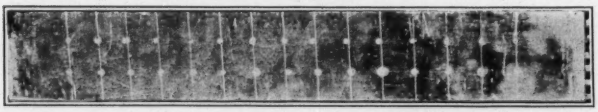
There was also some question as to the interpretation of the impressions. They were calibrated by static loading in the testing machine and also dynamically by falling weight. The calibration curves showing the results of both of these methods are shown in Figs. 8 and 9.

FIG. 6.



Recording track as subsequently modified to register at each end of each tie.

FIG. 7.

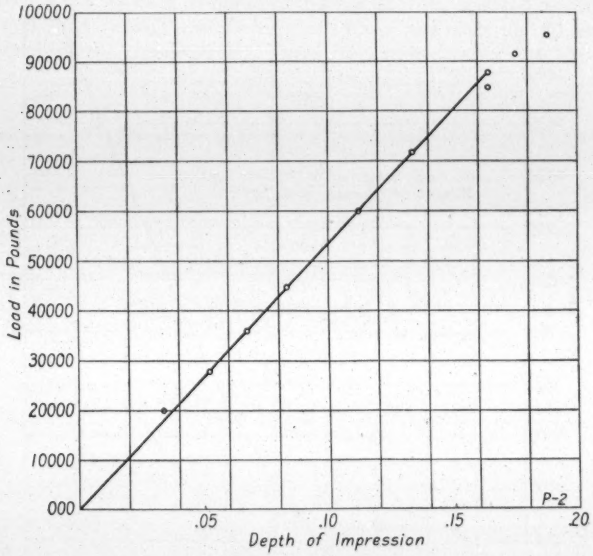


Strip showing impressions.

The recording ties, 80 in number, extending over five rail-lengths, or a total distance of 165 feet, were laid on a one-degree curve in the southbound track, near Franklinville, New Jersey, in 1907. There were 16 of the recording ties to each rail-length and at every splice on both rails the two ties at the splice were so located that the joint between the rails came between the

ties, which at this point were 20 inches apart. The other 14 ties were spaced as uniformly as possible, taking into consideration the necessities for spacing at the rail joints. Tie No. 1 was placed about 28 feet south of the point of curve. The superelevation of the outer rail of curve was 3 inches, and the elevation

FIG. 8.



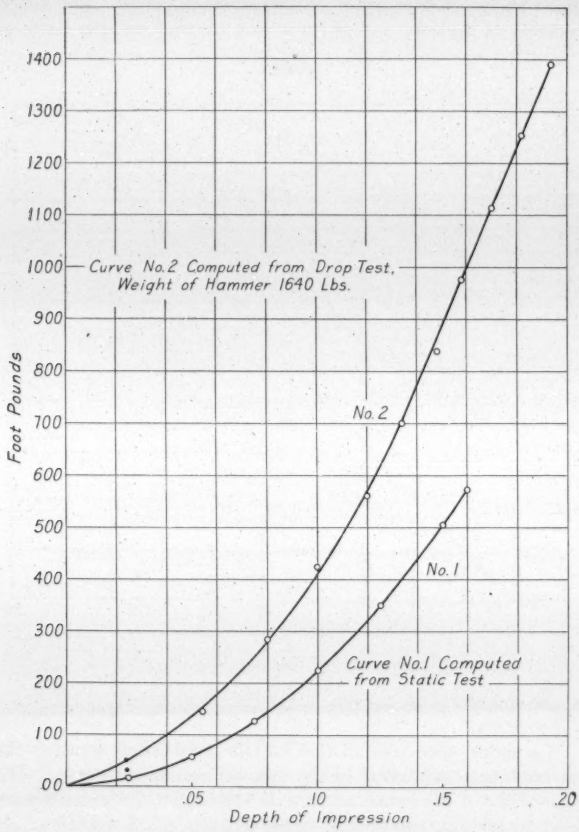
Static calibration of impressions.

of the rail began at a point about 250 feet north of the point of curvature.

Tie plates were used on wooden ties immediately south of the test track for one-quarter of the distance around the curve. The ballast used at the curve was gravel and cinder. The rails were P. R. R. section, 100 pounds to the yard, in good condition. It was specified in arranging the experimental track that it should be lined up in about the best average condition of track used on this piece of road.

The tangent track approaching the curve from the north consisted of 100-pound rails supported by wooden ties, single

FIG. 9.



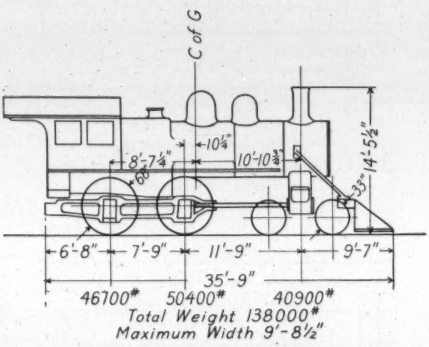
Calibration of impact test.

spiked. The substructure was of broken stone ballast with the exception of about 1500 feet north of the test track, in the

vicinity of Clayton, where most of the runs were started and where cinder and gravel ballast were used.

After the completion of the runs on the curve, the recording ties were removed to the tangent north of Franklinville station, where the trials were completed. At this location the track consisted of 100-pound rail with broken stone ballast. The speed record was obtained by means of a series of trips, operated by the locomotive passing over them, which broke and made the circuit going to the chronograph. These trips were located such dis-

FIG. 10.



American Type (4-4-0) Locomotive.

tance apart that at a speed of 100 miles per hour the time between trips would be one second. Four trips were used for the tests on the curve and seven for those on the tangent, the idea being that failure of one or two trips would not vitiate the record of the run.

Other apparatus used in the tests consisted of speed recorders on the locomotive, which were used only to obtain approximate speeds; and in some of the runs, there was placed on the locomotive a seismograph having three pendulums, giving vibrations in vertical, transverse and longitudinal directions.

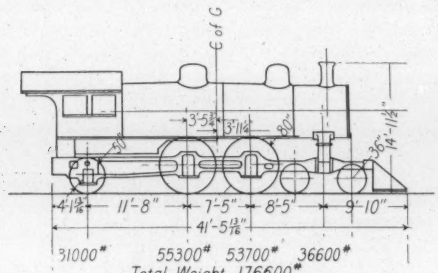
For the equipment, there was a choice of a wide variety of steam locomotives, and four electric locomotives were available.

The steam passenger locomotives elected were, one of the

4-4-0 or American type (Fig. 10), the other of the 4-4-2 or Atlantic type (Fig. 11).

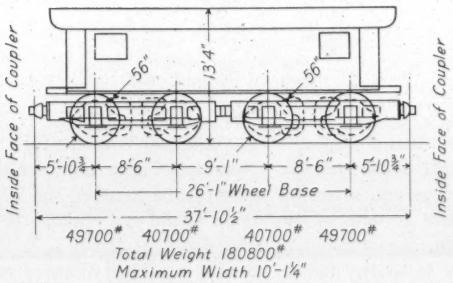
The electric locomotives were Nos. 10,001 (Fig. 12) and 10,002 (Fig. 13) already described; No. 10,003, or American type, that is, with two pair of driving wheels and a four-wheel

FIG. 11.



Atlantic Type (4-4-2) Locomotive.

FIG. 12.



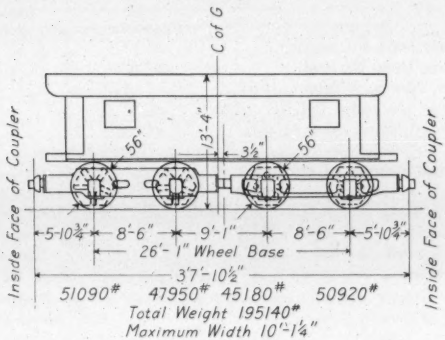
Electric Locomotive, No. 10,001, Geared Drive Type B.

truck (Fig. 14); and No. 028, a brand-new locomotive belonging to the New York, New Haven and Hartford Railroad, which consisted of two four-wheel trucks pivotally connected to the body which carried the draft attachments (Fig. 15).

The drives of Nos. 10,003 and 028 were very similar, consisting of a quill drive (type C).

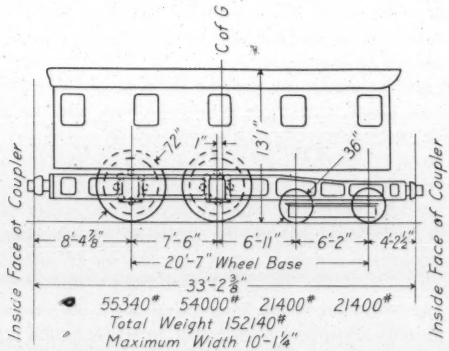
Locomotive No. 10,003 was arranged for A. C. operation, which necessitated provision for D. C. control operation, which

FIG. 13.



Electric Locomotive, No. 10,002, Quill Drive Type C.

FIG. 14.



Electric Locomotive, No. 10,003, Quill Drive Type C.

was placed in a separate car that always accompanied the locomotive.

No. 028 was arranged with double control, A. C.-D. C., so as to facilitate its operation into Grand Central Terminal, New York.

Considered from various standpoints these locomotives ranked as follows:

As regards wheel-base:

	Total Wheel-base	Distance center to center of trucks.
Electric Loco. No. 10,003	20′ 7″	17′ 6″
Electric Loco. No. 028	22′ 6″	14′ 6″
Steam, American Type (4-4-0)	22′ 9½″	19′ 6″
Electric, No. 10,001 and No. 10,002	26′ 1″	17′ 7″
Steam, Atlantic Type (4-4-2)	30′ 9½″	

As regards center of gravity:

	Vertically	Longitudinally
Electric Loco. No. 10,002	42½″ above rail	3½″ from center
Electric Loco. No. 10,001	45¼″	Centrally
Electric Loco. No. 028	55″	Centrally
Electric Loco. No. 10,003	55″	1″ ahead of front drivers
Steam, American Type, (4-4-0)	63″	10¼″ ahead of front drivers
Steam, Atlantic Type, (4-4-2)	73″	41¼″ ahead of rear drivers

Thus, if length of wheel-base is to govern, the Atlantic-type steam locomotive is the best, and the American-type electric, No. 10,003, should be the worst.

If height of centre of gravity is to be the deciding factor, the Atlantic steam locomotive is still the best, and the articulated quill-drive electric No. 10,002 the worst.

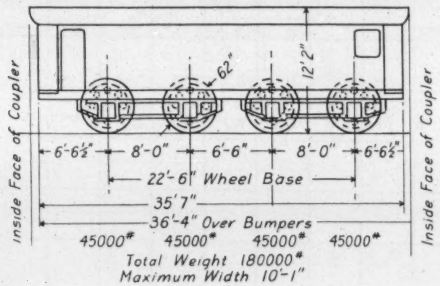
As the object of the trials was to determine stability at express speeds, very few of the runs were made at lower ones, but it is fair to say that with any type of locomotive, steam or electric, not much disturbance should be expected at low speed, consequently progressive speeds were selected up to the maximum speed capacities of the various locomotives.

The runs with the steam locomotives went off very smoothly. Typical records are shown at different speeds for each type (Figs. 16 and 17). The maximum speed for the 4-4-0 type was 83 miles per hour, and for the 4-4-2 type, 95 miles per hour. It is not to be understood that these are practical operating speeds.

When the electric locomotives were run the story was very different, as will be seen from the diagrams (Fig. 18). The record for the geared locomotive, No. 10,001 (type B), shows

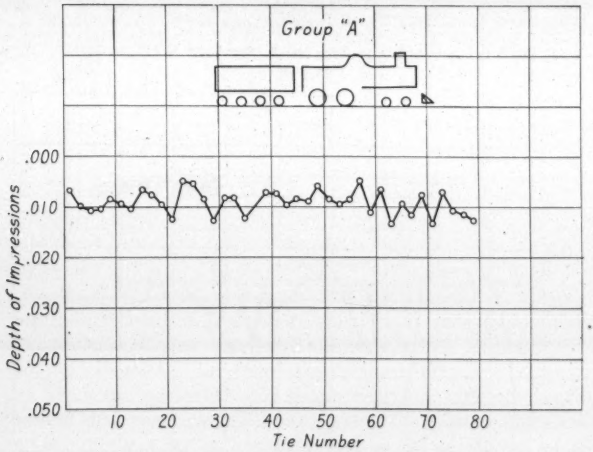
severe oscillation with either end leading, there being three rather pronounced peaks at about the same space interval.

FIG. 15.



Electric Locomotive, No. 028, Quill Drive, Type C. Pivotted Truck.

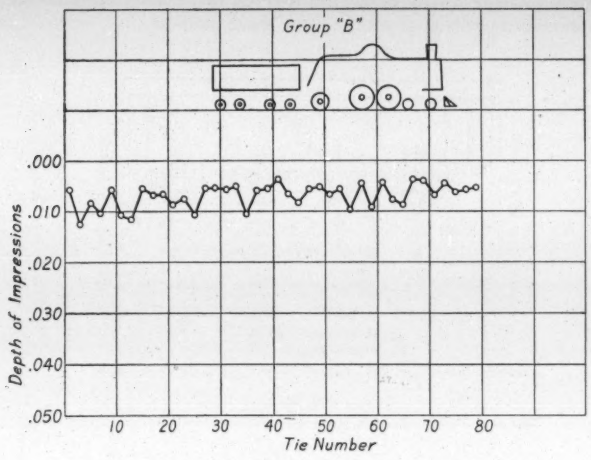
FIG. 16.



Steam Locomotive, American Type (4-4-0), Speed 83.5 M.P.H.on Curve.

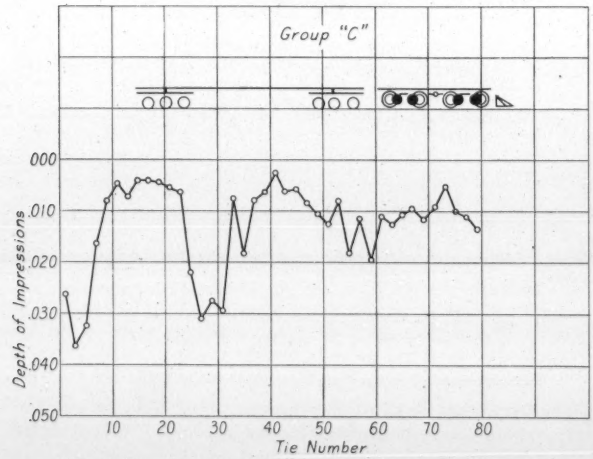
The maximum depth of impressions would indicate a lateral severity about double that with steam locomotives. It is probable that had the ties been arranged to record impressions at each end,

FIG. 17.



Steam Locomotive, Atlantic Type (4-4-2), Speed 95.7 M.P.H., on Curve.

FIG. 18.

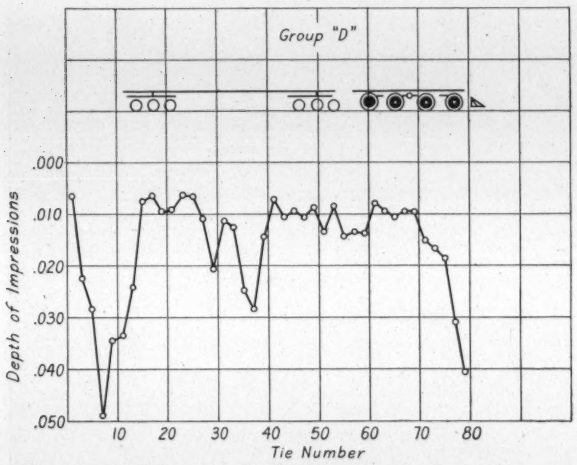


Electric Geared Locomotive, No. 10,001, Speed 71.5 M.P.H., on Curve.

intermediate impacts would have been shown on the opposite rail.

With No. 10,002, articulated quill drive, the records both of depth of impressions and of the seismograph were decidedly the worst of all the locomotives under trial (Fig. 19). While runs were being made with this locomotive the tangent approach track began to spread, with results shown in Fig. 20. The greatest spread was 7/8-inch, which caused kinking of the rail and bending of the spikes as shown in Fig. 21. The same thing hap-

FIG. 19.



Electric Locomotive, No. 10,002, Speed 68.3 M.P.H., on Curve.

pened in varying degree where runs were made with different locomotives coupled together, but only when locomotive No. 10,002 happened to be one of the combination.

With the non-articulated locomotive, No. 028, the readings both of the impressions (Fig. 22) and of the seismograph showed a very much better performance, and so far as this set of tests went, the locomotive could not be considered bad. It was, however, tried only on the tangent track after the completion of the tests on the curve. The subsequent history of this type of locomotive in service showed that as wear accumulated the lateral

oscillation became serious, so much so that the locomotives were changed by the addition of a third carrying axle to each truck, thus forming a non-symmetrical arrangement and at the same

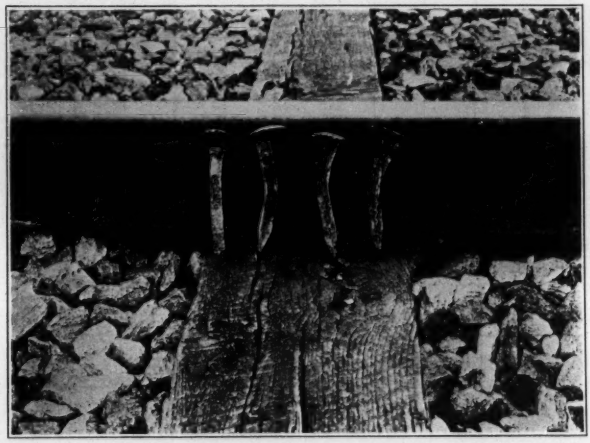
FIG. 20.

Tangent Track Kinked by Electric Locomotive No. 10,002.

time providing a longer wheel-base. In the light of subsequent tests, it is probable that the smoothness of the diagram for this locomotive was largely due to the absence of end play of the axles in their boxes.

The last of the electric locomotives, No. 10,003, was in fact an eight-wheel American-type locomotive, and the records on both curve and tangent at once put it in the class of the best steam locomotives (Fig. 23). As originally constructed the leading truck had free lateral motion, and an extensive set of runs in both directions showed that while the free swing was an advantage when the truck led, it was a disadvantage when it trailed, and that the best compromise was with truck rigid laterally.

FIG. 21.



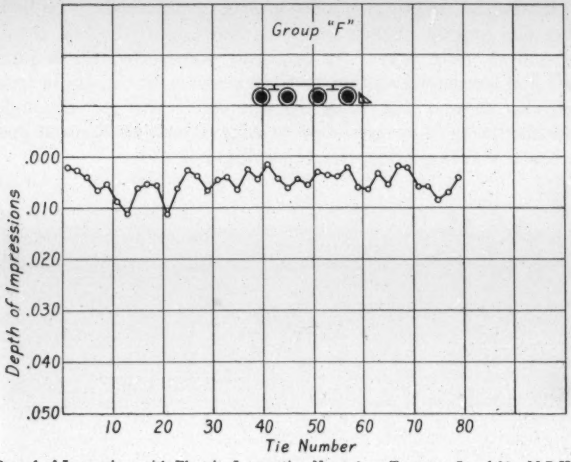
Spikes bent as result of lateral impact on tangent tracks.

These Franklinville tests concluded with runs of different combinations of locomotives coupled together. Apparently when the locomotives were coupled, the number of impressions was increased, but there was no material increase in the depth.

It appeared that in all combinations, including the articulated quill-drive locomotive No. 10,002, the riding of the companion locomotive was worse than when operated by itself (Fig. 24).

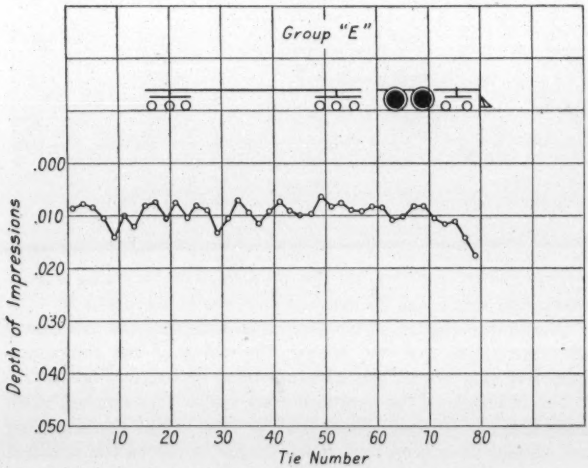
The influence of the approach track had a very marked effect on the results. It was evident that for best results the recording track should have been very much longer to record the resonant

FIG. 22.



Record of Impressions with Electric Locomotive No. 028., on Tangent, Speed 88.3 M.P.H.

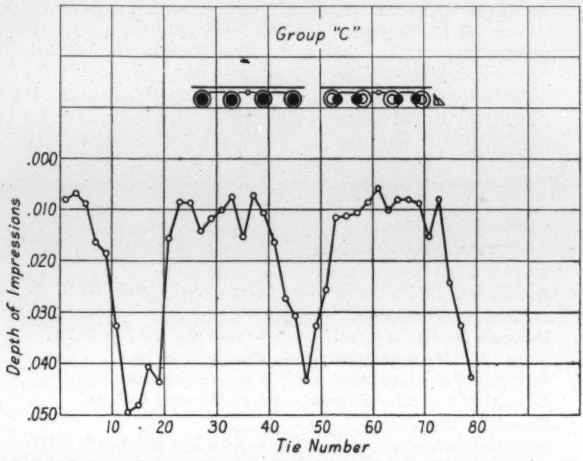
FIG. 23.



Record of Impressions with Electric Locomotive No. 10,003, (4-4-0), Speed 82.6 M.P.H. on Curve.

type of oscillations from their origin through their development to the final dampening. It was also evident that the ties should have been arranged to record on each end.

FIG. 24.



Record of Impressions with Electric Locomotives Nos. 10,001 and 10,002., coupled speed 71.6 M.P.H.,on curve.

The severity of the impacts from the impressions measured statically is indicated by the following notes on rail pressures at speeds above 60 miles per hour:

Group A—Steam Locomotive.

No. 6034, Type D-16b (4-4-0).

Maximum readings of 6 runs, speeds between 60.07 and 83.2 M.P.H.

At 60.07 M.P.H.—Impression .0135"—Pressure 7250 lbs.

At 80.0 M.P.H.—Impression .0141"—Pressure 7580 lbs.

Average—74.3 M.P.H.—Impression .0123"—Pressure 6610 lbs.

Group B—Steam Locomotive.

No. 6020, Type E-2, (4-4-2).

Maximum readings of 7 runs, speeds between 59.6 and 95.7 M.P.H.

At 71.2 M.P.H.—Impression .0129"—Pressure 6930 lbs.

At 80.8 M.P.H.—Impression .0159"—Pressure 6550 lbs.

Average—74.4 M.P.H.—Impression .0123"—Pressure 6500 lbs.

Group C—Electric Locomotive No. 10,001.

Forward, No. 2 end ahead.

Maximum readings of 6 runs, speeds between 61.1 and 71.3 M.P.H.

At 71.3 M.P.H.—Impression .0272"—Pressure 14620 lbs.
At 67.9 M.P.H.—Impression .0193"—Pressure 10370 lbs.
Average—64.5 M.P.H.—Impression .0165"—Pressure 8870 lbs.
Reversed, No. 1 end ahead.
Maximum readings of 4 runs, speeds between 60.9 and 70.1 M.P.H.
At 62 and 70.1 M.P.H.—Impression .0289"—Pressure 15530 lbs.
At 69.7 M.P.H.—Impression .0298"—Pressure 16000 lbs.
Average—65.7 M.P.H.—Impression .0267"—Pressure 14350 lbs.

Group D—Electric Locomotive No. 10,002.

Maximum readings of 4 runs, speeds between 60.8 and 60.8 and 68.1 M.P.H.
At 62.8 M.P.H.—Impression .039"—Pressure 20960 lbs.
At 66.0 M.P.H.—Impression .0311"—Pressure 16720 lbs.
Average—64.4 M.P.H.—Impression .0291"—Pressure 15640 lbs.

Group E—Electric Locomotive No. 10,003 (4-4-0).

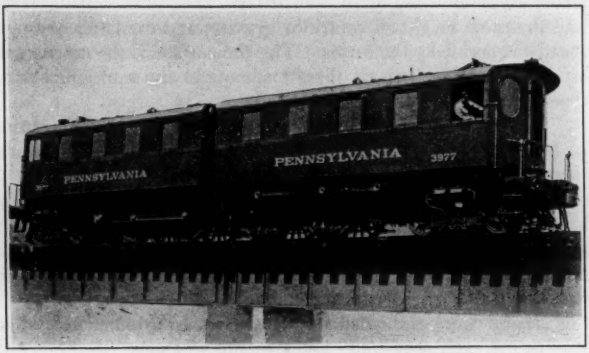
Forward, bolster free.
Maximum readings of 8 runs, speeds between 60.8 and 88.3 M.P.H.
At 63.3 M.P.H.—Impression .0123"—Pressure 6610 lbs.
At 72.38 M.P.H.—Impression .0125"—Pressure 6720 lbs.
Average—74.1 M.P.H.—Impression .0113"—Pressure 6070 lbs.
Forward, bolster blocked.
Maximum readings of 6 runs, speeds between 60.0 and 83.9 M.P.H.
At 75.1 M.P.H.—Impression .0179"—Pressure 9620 lbs.
At 83.9 M.P.H.—Impression .0193"—Pressure 10370 lbs.
Average—73.5 M.P.H.—Impression .0149"—Pressure 8010 lbs.
Reversed, bolster blocked.
Maximum readings of 5 runs, speeds between 65.5 and 84.0 M.P.H.
At 65.5 and 70 M.P.H.—Impression .0115"—Pressure 6180 lbs.
At 68.2 M.P.H.—Impression .0117"—Pressure 6290 lbs.
Average—74.04 M.P.H.—Impression .0106"—Pressure 5700 lbs.
Reversed, bolster free.
Maximum readings of 5 runs, speeds between 60.4 and 77.5 M.P.H.
At 68.9 M.P.H.—Impression .0289"—Pressure 15530 lbs.
At 70.2 M.P.H.—Impression .0281"—Pressure 15100 lbs.
Average—68.9 M.P.H.—Impression .0236"—Pressure 12700 lbs.

Group F—New Haven Electric Locomotive No. 028.

Maximum readings of 9 runs, speeds between 60 and 88.3 M.P.H.
At 70.7 and 72.6 M.P.H.—Impression .0197"—Pressure 10370 lbs.
At 70.8 M.P.H.—Impression .0186"—Pressure 10000 lbs.
Average—71.7 M.P.H.—Impression .0149"—Pressure 9000 lbs.

The outstanding fact seemed to be the superior performance of the locomotive with the non-symmetrical wheel arrangement over that with the double four-wheel motor-driven trucks. The articulated truck arrangement was undoubtedly the worst of the combinations, but how much of this was due to the low centre of

FIG. 25.



Type of Electric Locomotive Finally Adopted.

FIG. 26.

Chassis of Electric Locomotive Finally Adopted.

gravity and how much to the articulation setting up a snaking motion was not definitely established.

It is to be noted that one of the double truck motor-driven locomotives and one with two driven axles and leading truck had the same height of centre of gravity, and the latter arrangement was decidedly the better. The comparison is the more interesting because in both of these locomotives the same quill-drive type is used.

The action as the result of the tests was the condemnation of both types of articulated electric locomotives and the preparation of an entirely new design.

The new design consisted of two eight-wheel American-type locomotives coupled back to back, each driven by one motor in the cab and coupled by cranks and rods to a jack-shaft placed in the horizontal axis of the driving wheels, and coupled to them by rods, as in this case of steam locomotives (Figs. 25 and 26). In this design were embodied not only the non-symmetrical wheel spacing of each semi-unit, but also the elevation of the centre of gravity of the spring-borne portion. This design was completed and locomotives built and tested in time to start the operation of the New York Terminal in 1910, and the locomotives have satisfactorily performed that service ever since.

It is not claimed that the question of stability is fully understood. The selection of available wheel arrangements was very limited, but prompt decision was imperative. It is felt that this investigation should be considered as only a starting point for a much more extensive one, which should determine the most desirable arrangements of wheels, of height of centre of gravity, and method of motor drive.

So far as this particular investigation was concerned, the question of electric system was not involved, but, of course, a full discussion of the characteristics of steam and electric locomotives cannot ignore such questions.

Since this set of tests with single-ended ties, other series have been made in which the ties were arranged to record at each end. More ties were used so as to lengthen the test track. As for the equipment, the test included different methods of coupling the semi-units of electric locomotives; also studying the effect of depressions purposely placed in the approach track, the effect of different amounts of end clearance in the axle boxes, variation

in the amount of counterbalancing in steam locomotives, etc. The whole accumulation of data is too voluminous to be included in one paper. Although considerable practical information of value has resulted from the various trials, there is much work yet to be done before the questions of stability are really understood. It is to be regretted that the selection of electric locomotives did not include greater variations in the wheel-base, the method of articulation and height of centre of gravity, but it is believed that the work already done is a very good starting point for future investigations.

Study of Early Fossils. (*U. S. Geological Survey Press Bulletin No. 477*).—The fossil shells of the early invertebrates, or spineless creatures, are of great importance to geologists, for they indicate the geologic period in which the rock beds containing them were formed—in other words, the age of the rock. Each fossiliferous rock bed contains characteristic forms or groups of forms that determine the period in which it was mud or sand. Former Director Powell, of the United States Geological Survey, once tersely explained to a congressional committee the value of paleontology by saying that it is "the geologist's clock," by which he tells the time in the world's history when any rock bed was formed.

The economic importance of paleontology has been repeatedly shown in this country. In the earlier exploitation of anthracite coal thousands of dollars were fruitlessly expended in New York in search of coal beds, until the New York geologists showed that the beds in that State could contain no coal. The fossils in the New York rocks exploited are of Devonian age, whereas the fossils of the Pennsylvania anthracite coal beds belong to the Carboniferous, a much later period. This discovery at once stopped a useless expenditure of money.

In times of doubt and perplexity the geologist therefore turns to the paleontologist for light on the age and original order of the rock beds he is studying. The study of the animal and plant remains that are embedded in the rocks has thus become an important part of geologic work, and although the specialists who are engaged in this study are few, their work is of high importance.

High Altitudes in Montana. (*U. S. Geological Survey Press Bulletin No. 477*).—Six named peaks in Montana have elevations exceeding 12,000 feet, and several unnamed peaks rise to greater heights, according to the Survey. All these peaks are in the Beartooth National Forest, in Carbon County, in the south central part of the State. The highest of these is Granite Peak, 12,850 feet; the next highest is Mount Wood, 12,750 feet.

Bacteriologic Separation of Hydrocarbons.—MARTA PETER, in a thesis submitted to the Technical High-school in Karlsruhe, which was published in *Centralblatt f. Bakter., Parisit. u. Infect.*, in 1919, describes in much detail, experiments with bacteria which have the power to appropriate some aliphatic hydrocarbons, in the presence of certain cyclic hydrocarbons, but without affecting the latter. Three forms of bacteria are described termed, respectively, *B. aliphaticum*, *B. aliphaticum liquifaciens*, and one not definitely named, provisionally "paraffin bacterium." These organisms were obtained from garden earth. Full accounts are given of the methods of isolating and cultivating them, and their morphology. The test analyses were very numerous, and the investigator claims that a practical method for the analysis of petroleum oils has been developed. An interesting point in the paper is the fact that the cyclic hydrocarbons do not have any distinct restraining action on the growth of the bacteria used. H. L.

Detection of Carbon Monoxide.—The detection of this substance in air and other gases, when present in quite small proportion has been a problem of importance and of some difficulty. It is a very poisonous gas, having a special cumulative effect, by which the continued inhalation of very small amounts will ultimately produce serious conditions. C. R. Hoover, of Wesleyan University, gives an account in the *Jour. Ind. Eng. Chem.* (1921, xiii, 770) of the use of a new reagent, Hoolamite, which consists of fuming sulphuric acid and iodine pentoxide, mixed with an inert supporting material. This reagent was the subject of a patent by Messrs. A. B. Lamb and C. R. Hoover, from which presumably the uncouth name is derived. The inert material used is pumice. The reaction is the conversion of the reagent into a green mass, the depth of color being mainly proportional to the concentration of the carbon monoxide in the gas tested. Two portable devices are described by which tests may be made away from the laboratory and an approximate quantitative measurement made. It has been found that one of these devices is sufficiently sensitive to detect in a few seconds carbon monoxide in proportions believed to be harmless to human beings or the larger animals. The use of the instruments is not difficult, and it is hoped that very soon further improvements will be made in the preparation of the reagent and the operation of the apparatus. Carbon monoxide is, however, not the only gas which reacts, but all other gases, so far tested, that simulate it, are absorbed by dry animal charcoal, which does not appreciably absorb carbon monoxide. Some common gases are entirely without action. Hoolamite is a corrosive, deliquescent material, and must be kept in closed vessels. Its activity increases for a few days after preparation, then becomes stationary and remains so for a long while. It is usually kept in small sealed glass tubes. H. L.

ELECTROLYTIC WATER-PROOFING OF TEXTILE FABRICS: THE TATE PROCESS.* †

BY

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Member of the Institute.

PRIOR to the advent of the electrolytic method, the art of water-proofing textile fabrics was confined to two methods: Mechanical processes and chemical processes.

Mechanical processes embrace all methods which involve direct impregnation, filling or coating the fabrics with rubber, waxes and various compounds which achieve the result of rendering them proof against the penetration of both water and air. In view of the fact that the vast majority of the uses for which textile fabrics are designed requires that they possess the quality of ventilation, all of these mechanical processes are correlatively restricted in their application and are employed most largely in association with fabrics intended for specific uses wherein air circulation is a negligible factor; when used in associations where ventilation is an essential factor, notably for wearing apparel such as raincoats, the results are unsatisfactory from the viewpoints of both comfort and hygiene.

Chemical processes embrace all methods whereby a coating of a water-repelling substance is deposited on the surfaces, yarns or fibres of textile fabrics through the media of chemical reactions. These methods are designated as follows: (1) The *aluminium soap process;* (2) the *lanolin process;* (3) the *cuprate of ammonia process.* Since the electrolytic method of water-proofing described in this paper involves the impregnation of fibres with aluminium compounds, the first of these chemical processes will be described briefly.

In the aluminium soap process, which is one of the most largely employed where ventilation is an essential factor, the fabric is first saturated with a relatively heavy solution of soap and then passed

* Communicated by the Author.

† This paper embodies the results of an investigation of the Tate process of electrolytically water-proofing textile fabrics by the Committee on Science and the Arts of The Franklin Institute.

through a solution of alum, aluminium sulphate or aluminium acetate. Owing to the reaction which takes place between the soap and the aluminium salt, an aluminium soap (aluminium oleate or aluminium palmitate) is deposited on the yarns or fibres of the fabric in the form of a veneer or coating. While this veneer is fresh it is highly elastic, adhesive and water-repelling, but unfortunately these conditions subsist only for a short time. When the fabric is exposed to the drying influence of the atmosphere, deterioration is rapid, and in a few weeks the qualities of elasticity and adhesiveness disappear and the aluminium soap becomes friable, breaking away from its anchorage and thus restoring the fabric to its original absorptive condition. Furthermore, while the aluminium soap is insoluble in water, it is dissolved by gasoline, benzine and various other solvents employed in the process known as dry-cleaning. Garments water-proofed by this process cannot be dry-cleaned without partially or wholly destroying their water-repelling qualities.

The first mention of an attempt to apply electricity to the art of water-proofing textile fabrics is contained in U. S. Patent No. 558,717, issued to H. L. Brevoort in 1896. In Brevoort's process the fabric, previously moistened with water, is placed "between and in contact with an anode of an oxidizable metal and a cathode of conducting material covered with an absorbent fabric," and, owing to the physical contact between the surface of the anode and the fabric, the oxide formed at the positive electrode is deposited "on or in the fabric." Since, however, Brevoort did not provide any apparatus for applying his process on other than an experimental scale, his results are only of interest as experiments. Besides, fabrics treated by this method are but partially water-proof.

Four years later a patent [1] representing an attempt to provide a mechanism to apply the Brevoort water-proofing process to textile fabrics on an industrially operative scale was granted to J. T. van Gestel. However, in a second patent [2] of the same date, van Gestel abandoned his efforts to operate the Brevoort process and introduced one of his own which, in so far as the final physical results were concerned was similar to, but not identical with, the former.

The van Gestel process consists in first thoroughly impreg-

[1] U. S. Patent, No. 653,715, July 17, 1900.

[2] U. S. Patent, No. 653,716, July 17, 1900.

nating the fabric with a solution of a soluble metallic salt, capable of yielding an insoluble oxide on electrolysis, and then placing the wet fabric between non-oxidizable electrodes and passing an electric current through it. It is claimed that there is produced from the salt an insoluble oxide in the interstices of the fabric, whereby it is rendered water-proof. As a matter of fact the insoluble oxide would be precipitated at the surface of the cathode, and a fabric in physical contact with this surface would receive and retain a portion of this precipitate, but the penetration would be relatively shallow. Since, however, the negative electrode is surrounded with a muslin covering, it would seem that with an apparatus so arranged all the insoluble oxide would remain in the muslin and little or none of it would be in the fabric being treated. No record has been found of this process having been employed on a commercial scale.

In the Tate process of electrolytically water-proofing fibrous materials,[3] not only is the fabric impregnated with a water-repelling substance, but it is claimed that the inner capillary system of the fabric is filled with this substance.

This process was first installed on an industrial and commercial basis in the autumn of 1916, in the City of Montreal, where it was operated during the war by an imperial commission; and subsequently in New York City. In July, 1920, the New York plant was transferred to Cranston, Rhode Island, where an additional equipment has been installed to provide a maximum capacity of about 30,000,000 yards per annum of electrolytically water-proofed and electrically converted fabrics.

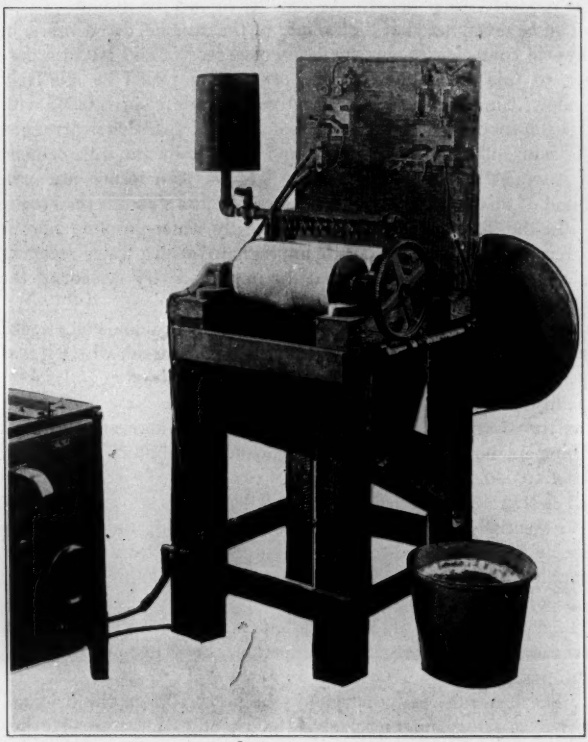
Essentially the Tate process consists in passing the fabric, previously saturated with a solution of sodium oleate, between a graphite cathode, over which flows a solution of aluminium acetate, and an aluminium anode which is completely enveloped in a heavy woolen pad. This pad is an important and distinctive feature of the invention, and before its introduction the water-proofing was quite irregular.

The historical development of the process from the original, crude, water-proofing mechanism, consisting of the small cylindrical anode and cathode shown in Fig. 1, covers four periods represented by as many types of water-proofing machines. With the first type of machine water-proofing was effected by passing the

[3] This process is covered by U. S. Patent, No. 933,861, issued September 14, 1909, and by several other patents issued subsequently.

fabric between pairs of rollers. The negative roll consisted of a cylinder of acheson graphite with electric contact through a collector brush at one end, while the positive roll consisted of a metal

FIG. 1.



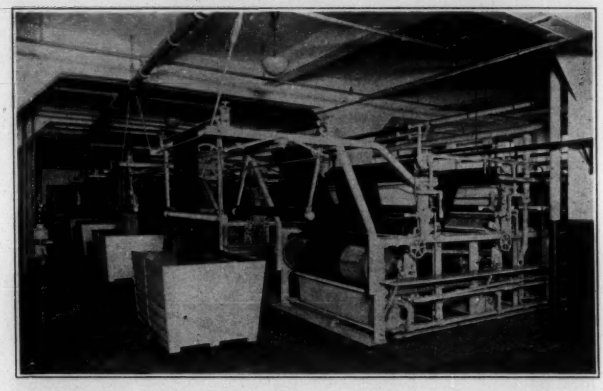
spider on which was spirally wrapped a one-inch square aluminium drawn bar. Inasmuch as a certain time period is required for the proper impregnation of the fabric, and since, furthermore, the rollers had a very small area of contact, the speed of this machine

had to be adjusted to permit of the necessary time interval for reaction. This limited the output on a single strand of fabric to about thirty-four inches per minute.

In the next commercial development, one of the roller electrodes was replaced by a stationary sector electrode for a length of contact of about five inches. In this machine the fabric was drawn between the one roller and the sector at a speed of about five yards per minute, and results obtained which were quite as satisfactory as those with the slower unit with two rollers.

In the third type of water-proofing machine, both rollers were

FIG. 2.



dispensed with and the material to be treated drawn between flat plate electrodes of aluminium and graphite, contact between the fabric and the electrodes being maintained by adjustable spring pressure. A battery of four of these machines is shown in Fig. 2. With this machine an output of about twenty-seven yards per minute was obtained as against an output of thirty-four inches with the first type of machine. Since in this unit no provision had been made for automatically relaxing the pressure when sewn lengths of fabric passed between the electrodes, the machine had to be stopped and the upper electrode lifted every time a seam came by, otherwise the fabric would tear. This difficulty has been overcome in the latest type of machine, a photograph of which (two units) is

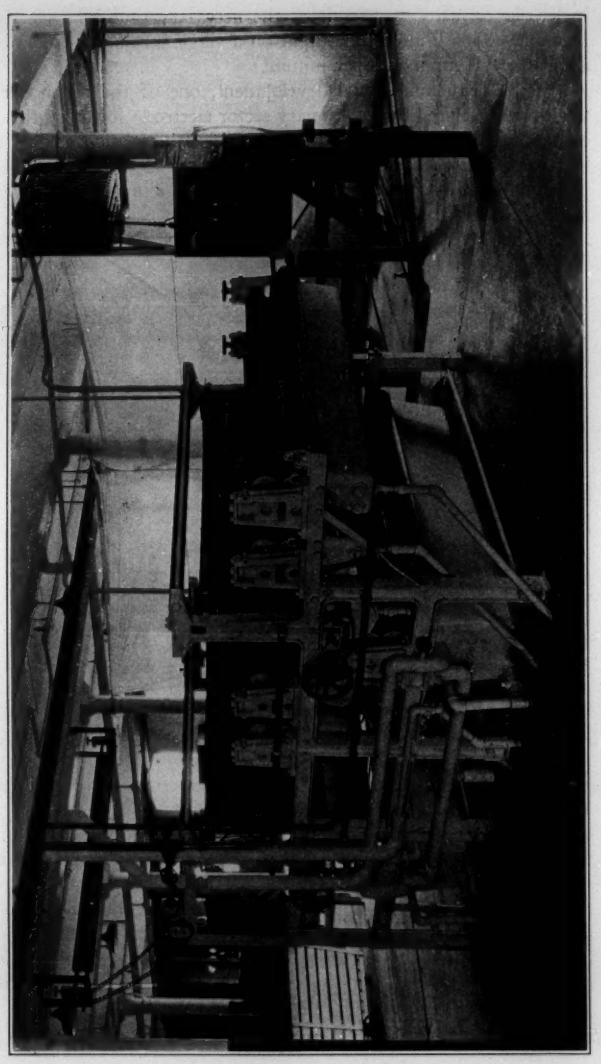
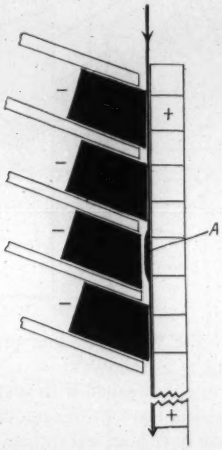


FIG. 3.

shown in Fig. 3, and a diagram (one unit) in Fig. 6. In this unit the electrodes are vertical, the anode consisting of an aluminium plate (7, Fig. 6) one inch thick by eighteen inches wide and either sixty or seventy-two inches long, and the cathode of eight graphite bars (8, Fig. 6) one and one-half inches thick by two inches wide and the same length as the anode. These graphite bars are spaced one-quarter inch apart, and their ends fit loosely between metal guides which are inclined downward toward the anode (Fig. 4).

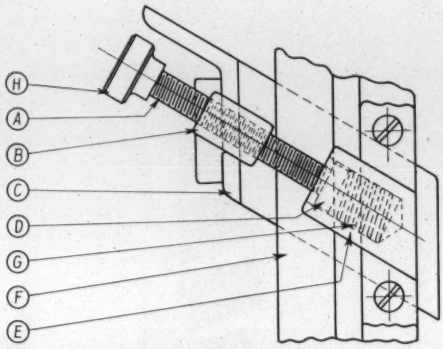
FIG. 4.



When a seam (A, Fig. 4) passes between the electrodes, each graphite bar in turn moves backward and upward and, when the seam has passed, immediately falls back to its original position. Recently a spring device (10, Fig. 6) has been installed on the vertical graphite electrodes for the purpose of permitting a delicate regulation of the pressure of each segment of the electrode on the fabric. With this device the operator can maintain a constant tension on the material being treated, regardless of its character or thickness. This regulation is very desirable and a decided improvement over the form of gravity contact, which exerted the same pressure for the finest silk or the heaviest duck. The

mechanical form of this device, shown in detail in Fig. 5, consists of a brass screw, A, threaded through a bracket, B, which is attached to each end of every graphite segment, C. The bottom end of these screws is in the form of a plunger which enters the cylinder, E, this being suitably attached to the electrode frame, F. This cylinder contains a spring, G, which is compressed by the plunger when the screw is tightened down by the small insulated knob, H.

FIG. 5.



The operation of the water-proofing process with the most recent type of machine is as follows:

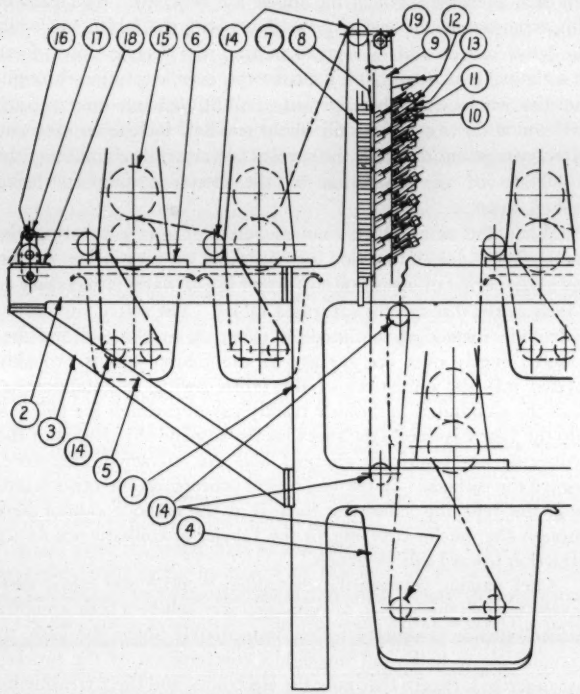
Woolens are thoroughly washed with soap and rinsed in water at a temperature of about 150° F. to remove any excess of wool grease or soap that may have been left during the process of manufacture. Cottons are all destarched by a suitable process and freed from all foreign matter. In both cases this is done with the object of cleansing the fibres and opening their capillary pores for subsequent refilling with water-repelling substances.

The fabric then enters the water-proofing machine, Fig. 6, where it is saturated with an attenuated solution of sodium oleate (preferable to sodium palmitate) contained in each of the two baths, 8. From these baths it travels up over the brass idler roll, 14, and passes downward between the electrodes, 7 and 8, between which a current of from 30 to 60 amperes flows, the current density depending upon the nature of the fabric and the character of the

treatment required. The course traveled by the fabric is shown by the broken line in Fig. 6.

From troughs, 13, connected with a suitable supply system, the aluminium acetate solution is fed between each of the one-quarter

FIG. 6.



1. Frame. 2. Frame Extension. 3. Frame extension support. 4. Wash tank. 5. Solution tank. 6. Quetch frame. 7. Anode-aluminum. 8. Cathode-graphite. 9. Graphite support-side. 10. Graphite adjuster. 11. Graphite support-end. 12. Acetate trough support. 13. Acetate trough. 14. Idler roll-brass. 15. Quetch idler roll-rubber. 16. Tension rod. 17. Tension rod holder. 18. Tension rod holder bracket. 19. Frame spreader rod.

inch openings separating the graphite segments of the cathode, 8. On coming into contact with the sodium oleate contained in the fabric, the aluminium acetate reacts with it to form an insoluble

aluminium oleate which is deposited on the surface of the fabric. A thorough and even distribution of the aluminium acetate is effected by means of a number of ducts on the contact face of each graphite segment. These ducts are cut one-eighth inch half-round at an angle of 45° with about one and one-quarter inch intervals. On each alternate segment the angles are reversed. By means of this arrangement the acetate flows down with the fabric, but while the latter moves with a vertical motion, the acetate flows down in a zig-zag path, maintaining a constant, even saturation throughout the whole electrolytic period. Additional one-quarter inch half-round ducts cut vertically about one-half inch from each end of every segment drain off the surplus acetate, thus eliminating the possibility of the insulation of the electrode supports being broken down.

When the woolen pad (not shown in Fig. 6) covering the anode, 8, first goes into action it is saturated with water, but during any given period of operation no further use of water is necessary as it then works through the saturated fabric. The active aluminium hydroxide formed at the anode is taken up by the pad and distributed evenly over the surface of the fabric, and is probably carried into the interstices of the fabric owing to kataphoresis. That the aluminium hydroxide readily passes through the pad and into the fabric is due to the fact that the suspended particles of the hydroxide are positively charged and are attracted, therefore, toward the cathode. In the van Gestel process, on the other hand, the water-repelling substance formed at the cathode cannot pass through the muslin covering to the fabric, in consequence of its attraction toward this electrode.

After passing between the electrodes, 7 and 8, the fabric then travels through the bath, 4, of running water, where it is thoroughly washed; thence to squeeze rollers immediately above the bath, to a second oleate bath, and through a continuation of the process just described, except that now the electrodes and their treatments are reversed. With cotton goods, irrespective of their weight and thickness, four treatments are essential with alternately reversed action. With silks and woolens two treatments—one reversal—are sufficient. This is due to differences in the physical structure of cotton, silk and wool fibres.

When the electrolytic treatment is complete, the fabric is

washed, dried by passing between a series of steam-heated drums, and rolled or folded.

The writer has examined and tested various kinds of textile fabrics that have been water-proofed by the process described, and has found that they possess remarkable water-resisting qualities. For example, tests on the resistance to water pressure, carried out with a thin cotton that had been water-proofed for making light-weight tents, showed that whereas the untreated cotton broke down under a water pressure of one-half inch, water did not pass through the electrolytically treated material until the pressure attained twelve and one-quarter inches. Regarding the service-ability of this water-proofed tent material, the following quotation from the letter of a camper may be of interest:

> I am enclosing a picture taken on my canoe trip down the Whitefish last summer that shows you just how useful the eight-foot square of light-weight tent cloth, water-proofed by the Tate process, which you lent me, proved to be.
>
> Coming back we struck two days solid rain, and the little water-proof patch was a wonder. We used it nights as a tent and days as a cover over our duffle, and though wet all the time, it never leaked a drop. I wouldn't have believed it possible if I hadn't slept dry as a bone under it two soaking nights.

Determination of the maximum water pressure that could be sustained by a number of samples of untreated and electrolytically water-proofed duck led to the following observations: Invariably when an untreated piece of duck broke down and water flowed through, it was found that on releasing the water pressure and re-applying it, water began to leak through the duck immediately; on the other hand, with the treated material, when the pressure was released after the water first leaked through, it was found that the pressure could again be raised to the first value before leaking recommenced. Unlike the untreated duck, when the maximum water pressure is reached with the water-proofed material the water does not leak through in one or two places but in a large number. Notwithstanding the marked water-resisting qualities of the water-proofed materials, these are found to contain but 0.3 to 0.4 gram of aluminium oxide per square foot.

In order to ascertain the efficacy of the electric current in the process that has been described, two tests have been carried out with the three following samples of very heavy duck taken from the same roll: (A) *Untreated duck;* (B) *duck that had passed through the electrolytic water-proofing machine and subjected to all*

the conditions of the normal water-proofing process, except that the electric current was not flowing; (C) *duck that had been subjected to the normal electrolytic water-proofing process. Test No. 1.* Small seamless bags of the same shape and size were made from the samples A, B, and C. These bags were suspended and the same volume of water was added to each. The water leaked through the bottom of A at the end of one and one-half seconds; through the bottom of B at the end of thirty-one seconds; while at the end of three weeks no water had leaked through C. *Test No. 2.* Portions of the samples A, B, and C were dyed under the same conditions with a dye the action of which depended on the presence of an aluminium mordant. Sample A took up but very little of the dye; sample B was dyed a deep red, and sample C a very much deeper shade, thus indicating that while the chemically treated sample B contained aluminium compounds, the electrolytically treated sample C contained much more.

It might be supposed that the fabric would be tendered by the water-proofing process. This is not so, however, as experiments show that there is an actual increase in the strength of the fabric approximately equivalent to the increase in the filature.

A study of the electrolytic water-proofing process has led to the conclusion that the water-proofing of fabrics is due to two distinct electro-chemical operations: One, the electro-chemical formation at the anode of aluminium hydroxide which, owing to kataphoresis, is probably carried into the capillaries of the fabric; the other, the deposition on the fabric (probably only on its surface) of a film of a basic aluminium oleate resulting from the interaction of aluminium hydroxide formed electro-chemically at the cathode with the aluminium oleate produced chemically by the aluminium acetate flowing over the cathode and the sodium oleate contained in the fabric. The formation of a basic aluminium oleate, and not ordinary aluminium oleate, at the cathode, is substantiated by the fact that although both ordinary aluminium oleate and the aluminium oleate formed in the electrolytic process are insoluble in water, the former is soluble while the latter is insoluble in liquid hydrocarbons such as gasoline and benzine. Moreover, chemical analyses of the aluminium oleate scraped from the negative electrode during its formation have shown that this substance contains a considerably higher percentage of aluminium than ordinary aluminium oleate, thus proving it to be a different compound.

In addition to water-proofing, all fabrics treated by the Tate process become mildew-proof, as attested by numerous tests under conditions to which untreated fabrics invariably succumb. This feature is not attributable to any germicidal qualities of the metal salts employed, as they no not possess this property. It is due to the fact that the water-proofed fabrics receive under impact or bombardment only relatively small quantities of water, the surface penetration being very shallow, and do not, therefore, retain moisture for periods sufficiently prolonged to effect the cultivation and growth of the germ. It has been found that if treated fabrics are kept in constant contact with still water in a mildew-laden atmosphere at relatively high temperatures, they will succumb to the attack in a period of about five weeks, but this environment is rarely encountered under general service conditions. In its relation to textile fabrics of cotton manufacture, as used for tents, awnings, sails, tarpaulins and similar coverings exposed to the elements, this feature involving preservation and prolonged utility is in many instances quite as valuable as the water-repelling quality.

The influence of aluminium salts in fixing dyes is well known, and the electrolytic process, involving as it does the use of these salts, will probably fix many fugitive dyes and render them impervious to the dissolving action of water.

The electrolytic water-proofing process also performs coincidentally and thoroughly the operation of shrinking, and all fabrics thus treated are less liable to subsequent structural change of this nature through atmospheric or other action due to the influence of moisture. Microscopic examination shows that the process straightens the fibres and sets more evenly the threads or yarns of the warp and woof in fabrics wherein unevenness in this respect is present. Indeed, the changes wrought in goods of cotton manufacture bring about a complete transformation and, altogether apart from the water-repelling qualities imparted, add intrinsic value through the production of a new and better class of fabrics as judged by the recognized standards of the textile industry. This converting process does not, however, stop here. It has been found that upon calendering cotton or worsted fabrics, under ascertained conditions of temperature and pressure subsequent to water-proofing, higher surface lustres are attained than under standard finishing conditions. These lustres vary in degree from the depth

sheens usually associated only with natural silk fabrics to the brilliant surfaces which distinguish the most highly finished satins; and it is remarkable that these visual characteristics are in each instance confirmed and emphasized by the sense of touch. All of these conversions are effected without in any way impairing the water-repelling qualities originally imparted to the fabrics.

In conclusion, it will be seen that the development of the Tate process as applied to textile fabrics of all classes has advanced so far beyond the isolated achievement of rendering these materials non-absorbent, and has effected changes so entirely novel and comprehensive in their ascertained scope and potential significance, that the term water-proofing conveys a totally inadequate conception of the field which the process embraces. The electrolytic treatment represents a combined process of water-proofing and converting, while in the succeeding stage of calendering, the weave, shade, color and texture of fabrics other than woolens may be altered to predetermined degrees, producing in each instance a new and higher class of fabric, as compared with the original and as judged by recognized trade standards.

SWARTHMORE, PA.,
June 17, 1921.

A Photographic Seismograph.—The seismograph is an instrument for recording earthquake shocks. The instruments in general use are so constructed that a strip of paper records any vibration, and the time of any special disturbance can be noted. The principle of construction requires a delicate adjustment of levers and amplifiers of the motion. By the introduction of sensitive paper instead of the method of inking, a simpler apparatus has been obtained, which is described by Doctor Bomet in *Photo-Pratique*. A small mirror, capable of oscillating with any earth-movement, receives a beam of light and reflects it upon a strip of sensitive paper. As the reflected ray moves through an angle which is twice that of the angular motion of the mirror, the oscillations are increased two-fold in extent. The strip of paper is, of course, kept in constant and regular movement. The mechanical construction is given in detail in the article, but need not be repeated here. Electric lamps are used for illumination. From time to time the paper strip is removed and developed and gives a clear picture of the movements to which the apparatus has been subjected. It is now well-known to experts in this field that earthquake shocks often pass through places without attracting any attention from the inhabitants. It is stated that the tremendous volcanic explosion in the Indian Ocean in 1885, by which a large part of the island of Krakatoa was destroyed, produced seven successive shocks around the earth. H. L.

X-RAY AND INFRA-RED INVESTIGATIONS OF THE MOLECULAR STRUCTURE OF LIQUID CRYSTALS.*

BY

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Government Research Fellow, James Buchanan Johnson Scholar, Johns Hopkins University, Member of the Institute.

X-RAY INVESTIGATION.

It has been shown by Lehmann and others that the optical properties of liquid crystals [1] are influenced by the surfaces between which the liquids are enclosed, so much so that Lehmann contends that "liquid crystals" have a space-lattice when they are enclosed between "similar and similarly orientating crystalline plates."

In order to bring the substance under investigation into direct contact with similarly orientating crystalline plates, a thin rectangular plate of mica was clamped along one edge and carefully split open from the opposite edge into the form of a wedge. Some finely powdered p. azoxyanisole was placed in this wedge. This wedge was gradually heated on a copper plate, and after the crystalline powder had melted the air bubbles were squeezed out at the open end. On cooling the enclosed layer of p. azoxyanisole presented a fairly uniform crystalline appearance under the microscope. This preparation was placed in the heating spirals,[2] and a series of photograms were obtained when the substance was in the solid, plastic and liquid states.

Each photogram gives the mica "point pattern" and the pattern of the substance between the mica plates. By comparing these patterns one can eliminate the mica pattern and thus obtain the pattern due to the substance only.

On transmitting a parallel pencil of X-rays through the thin solidified layer of p. azoxyanisole the pattern showed several fairly large (about 1 mm. diameter), irregularly shaped spots which indicated that the crystalline layer is made up of small crystal units of about 1 mm. in cross-section.

* Communicated by Dr. J. S. Ames.

[1] See this Journal page 651, 1921.

[2] Ibid.

On heating the cell the crystalline layer becomes plastic. This can be tested by viewing the layer through a microscope and observing the sliding when a knitting needle is lightly pressed against one of the plates. In this state the photogram clearly shows that the substance still possesses a space-lattice. It gives a point pattern consisting of a few irregularly shaped spots, which do not give any indication of the type of crystal symmetry.

On increasing the temperature of the cell until the layer became an anisotropic liquid, and transmitting a parallel pencil of X-rays through it, a new type of pattern was obtained after an exposure of forty hours. It consists of a series of faint horizontal lines, which are about 1 mm. broad for those lines which pass through the central spot. Farther off they are fainter, thinner, and more closely spaced. If this phenomenon be due to diffraction from parallel layers of lamellar molecules the spacing between the molecules must be of the order of 40 A units. This point will be further investigated in the near future.

INFRA-RED INVESTIGATIONS.

Abney and Festing, Julius, Puccianti, Aschkinass, Rubens, Coblentz and others have shown that radicals have distinctive absorption spectra, moreover Julius, Puccianti and subsequently Coblentz have shown that the bonding of atoms in isomeric compounds has a great influence on the absorption spectrum whereas stereomeric compounds investigated by Coblentz show no change in their absorption spectra.[3]

Angström, Rubens and Aschkinass showed that the spectra of liquids and their vapors are identical, and in 1906 Pfund showed that the selective reflections from solid and from molten crystals are identical, whereas the spectrum of sulphuric acid changes with dilution.[4]

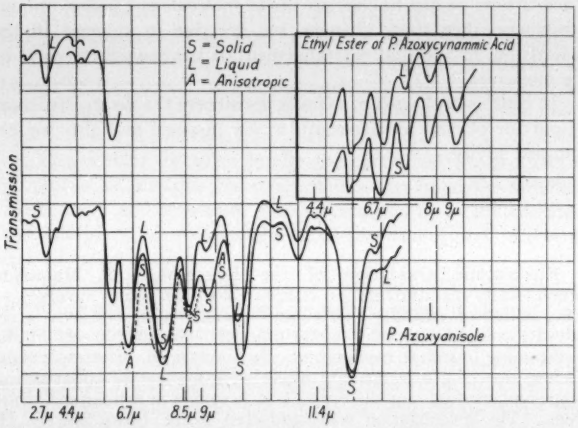
From the above-mentioned investigations it appears that any change in the molecule of a compound will be accompanied by a change in the absorption spectrum of the compound.

This method of investigation enables one to determine whether the absorbing mechanism of the molecule changes when it is subjected to physical changes. In order to find whether any change takes place in the molecule of those solids which give rise to liquid

[3] Coblentz: Investigations of Infra-red Spectra, Carnegie Publication 1905.
[4] *Astrophysical Journal*, 24, 1–19, 1906.

crystals in the molten state, a heating apparatus was constructed out of two concentric hollow cylinders: The inner one having a flange and a corresponding plate between which two rock salt plates containing the substance under investigation could be clamped. The outer cylinder was wound with resistance wire between asbestos sheeting. Radiations from a Nernst glower were brought to a focus by a mirror on the cell, and a second mirror projected this image on the slit of the spectroscope consisting of a Wadsworth mirror and rock salt prism arrangement

FIG. 1.



Transmission curves of p.azoxyanisole and of ethyl ester of p. azoxycynammic acid.

and a delicate thermocouple and galvanometer. A milled-head connected to a tape served to rotate the prism.

The method of procedure was to read off the galvanometer deflection when the cell was removed and when the radiations had passed through the cell and from these readings the percentage transmission was calculated. Beyond 3μ a long series of readings could be obtained without changing the slit width. This enables one to use the same portion of the cell throughout, whereas at shorter wave-lengths the cell had to be removed at frequent intervals to obtain the "air curve" for the same slit width. This method does not give concordant results with regard to percent-

ages as a small change in thickness of the layer penetrated shows a marked influence on the transmission. It does not, however, affect the positions for minima transmission.

For this work p. azoxyanisole and p. azoxycynammic acid ethyl ester were used.[5] If any change takes place in the bonding of the atoms in the radicals one would expect to find a marked change in the spectra in the region 6μ to 10μ. From the figures it appears that the spectra of the solid, the anisotropic liquid and the amorphous liquid are the same, hence no change has taken place in the bonding of the atoms in the radicals. If changes in space-lattices be due to changes in the molecules of polymorphous substances, then these changes are not due to changes in the radicals but to a spatial rearrangement of the component parts of the molecules.

In conclusion I wish to express my sincere thanks to Professor Pfund for placing his apparatus at my disposal and also for his help and advice.

BALTIMORE, MD.
JULY 6, 1921.

Electrolytic Oxidation of the Leuco-base of Malachite Green.—The manufacture of standard coal-tar colors involves so many points of difficulty that extensive and minute research is required to obtain constancy in the product. Advance sheets of the forthcoming (40th) meeting of the American Electrochemical Society describe experiments made with a view of substituting electrolytic methods for the use of lead peroxide in making malachite green. The investigation was conducted by A. Lowy and E. H. Haux, in the department of chemistry, University of Pittsburgh. The commercial method with lead peroxide is to add this substance in slight excess, filter out the insoluble lead compound and precipitate such lead as has passed into solution by means of sodium sulphate. The equations for the reactions involved are given in detail. Experiments with an electric current showed that no satisfactory result can be obtained without a catalyst, and uranyl nitrate was found to be the best of those tried. A nichrome gauze anode in dilute sulphuric acid at 85° C. was used. A moderately high temperature is essential. The gauze dissolves in the acid which makes its use objectionable. The usual method with lead peroxide is carried out in the cold.

H. L.

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[5] These substances were kindly placed at my disposal by Professor C.W. v.d. Merwe, of Stellenbach University, South Africa.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

METALLOGRAPHIC TESTING.[1]

[ABSTRACT.]

THE value of the results of a metallographic examination as related to the testing of metals is now generally recognized. While the mere determination of certain mechanical properties may be sufficient as a routine procedure of testing, for a complete working knowledge of metals and alloys, a much more extended study, particularly of the conditions which determine the properties is necessary. The study of these fundamental conditions, structure, constitution, mechanical and thermal treatment, etc., constitute the subject of metallography, the term being used here in a broad sense and not limited to microscopic examination as was formerly the custom.

The circular discusses briefly the conditions which affect the properties of metallic materials under the following headings: Microscopy and structure, thermal analysis and heat treatment, mechanical working of metals, chemical metallurgical factors and conditions of melting.

The structure of metals is dependent upon the previous treatment the material has received as well as upon its chemical composition. Such structural features as homogeneity or the lack of it, grain size, and physical soundness of the metal, are of grave importance in determining the properties of a material. The microscopic examination has proved of great value in the study of materials which failed in service.

The thermal characteristics determine largely the heat treatment which may be given an alloy which is of such vital importance in the alloy steels in developing high mechanical properties.

Mechanical treatment is necessary for putting the material in a shape suitable for use. The properties are at the same time very materially influenced by the working and it is the effect of mechanical treatment rather than the mere shaping of the piece that is of importance in metallography.

The term "chemical metallurgy" as used in the circular is employed in a very special sense. The general metallurgical

* Communicated by the Director.

[1] Circular No. 42, 2nd ed.

processes such as the concentration and smelting of ores and the like are not discussed but the term is limited to a consideration of those features of composition, generally resulting from special treatment during preparation, which appear to have a marked effect upon the physical properties of the metal. The occurrence of gases in metals may be cited as an example.

For metals and alloys which are to be used in the cast state, the conditions attending the melting and casting of such materials are of prime importance in determining the properties of such materials. For metals which are to be given further treatment subsequent to casting the conditions of melting of the metal must also receive due consideration.

The circular summarizes the conditions under which tests of a metallographic nature will be conducted by the Bureau of Standards. Specific directions concerning shipping, sampling, etc., are given.

ZINC CYANIDE PLATING SOLUTIONS.[2]

By William Blum, F. J. Liscomb and C. M. Carson.

[ABSTRACT.]

ZINC plating or electrogalvanizing was extensively applied during the war because of the fact that zinc coatings furnish by far the best protection against corrosion of steel. Satisfactory zinc deposits can be secured from either sulphate or cyanide solutions but the latter possess the advantage of "throwing" the deposit better into deep depressions or upon the surface of irregularly shaped articles. The cyanide solutions were therefore given first consideration in this investigation. It is hoped later to extend this study to include the sulphate solutions.

It was found that satisfactory zinc cyanide plating solutions can be made by using zinc oxide to replace part or all of the zinc cyanide formerly employed for this purpose. In the analysis of such solutions zinc may be determined by the customary methods. It was not found possible to obtain by the usual methods any reliable results for either "free cyanide" or "free alkali." It is possible, however, to make fairly accurate determinations of the

[2] Technologic Paper No. 195.

total cyanide content and total hydroxide content from which data the probable constitution of the solutions can be computed.

It was found that the following conditions yield satisfactory results in practice. A solution may be prepared according to the following formulas, in which the concentrations have been rounded off to convenient values:

	Approx. normality	g/L	oz/gal
Zinc oxide	1.0	45	6
Sodium cyanide	1.5	75	10
Sodium hydroxide	.3	15	2
or			
Zinc cyanide	1.0	65	8.7
Sodium cyanide	.3	20	2.7
Sodium hydroxide	1.5	60	8

It should be operated at temperatures below 40° C. (140° F.) in order to reduce the decomposition of the cyanides. Current densities up to 3 amp/sq. dm. (28 amp/sq. ft.) may be employed upon smooth surfaces but for general work about 2 amp/sq. dm. (19 amp/sq. ft.) is preferable. The presence of large amounts of carbonate causes rough or striated deposits. Carbonates should therefore be removed from the solution at intervals by precipitation with barium cyanide or hydroxide, or by cooling the solutions to low temperatures.

RESULTS OF SOME TESTS OF MANILA ROPE.[3]

By A. H. Stang and L. R. Strickenberg.

[ABSTRACT.]

The results of tests on manila rope discussed in this paper represent some of the data which have accumulated at the Bureau of Standards during the past few years.

Most of the specimens were submitted by various rope manufacturers on purchase orders for government departments. A fixed procedure was adopted by the laboratory for all rope tests.

The rope ranged in diameter from ½ to 4½ in. inc., and consisted of commercial three strand regular lay ropes. The breaking load, weight per linear foot, number of yarns and

[3] Technologic Paper No. 398.

the lay of the rope and strands, as well as the elongation, were measured.

The average breaking load was found to be approximately a quadratic function of the diameter of the rope. It is expressed quite closely by the equation

$$L = cd\ (d + 1)$$

in which L is the load in pounds, c is a constant equal to 5000 and d is the diameter of the rope in inches.

The ropes showed a continually varying modulus of elasticity and no well-defined proportional limit.

The number of yarns composing a rope may be expressed approximately by the equation

$$N = kd\ (d + 0.4)$$

where N is the number of yarns, k is a constant equal to 50, and d is the diameter of the rope in inches.

The test results cover sufficient range and show such consistency that it is believed that the formulas deduced may be used safely for three-strand regular lay manila rope for sizes of rope between ½ and 4½ inches in diameter.

TESTING OF THERMOMETERS.[4]

[ABSTRACT.]

THE previous edition of this circular contained, in addition to the testing regulations, much general information on thermometry and temperature measurements. The present edition has been very much shortened by including only the information which is essential to those who avail themselves of the Bureau's testing facilities.

The Bureau's standard scale of temperature is defined, and the method of reproducing it is briefly indicated. The facilities of the Bureau are such that practically all types of laboratory thermometers can be tested, but thermometers of the so-called industrial or mechanical types will not, in general, be accepted for tests because of lack of equipment for making such tests.

In testing laboratory thermometers the Bureau will usually decide upon the number and position of test points required, the choice depending upon the purpose for which the thermometer is to be used, when this purpose is known.

[4] Circular No. 8.

A new feature of the circular is the inclusion of definite test requirements and of tolerances as to correctness of graduation. Thermometers meeting the requirements as to suitable design, material and workmanship, will, if found correct within the established tolerances, be certified, others will receive reports giving the results of test. There are separate tables of tolerances for Centigrade and for Fahrenheit thermometers, and for total and for partial immersion thermometers.

Notes on the behavior of thermometers are intended to give the user of the thermometers the information necessary for an intelligent use of the results of a test. When it is recognized that the reading of a thermometer at a given temperature may be changed as much as 0.1° by a few minutes heating to a higher temperature, it is evident that the thermometer must be used under carefully specified conditions if an accuracy of 0.02° is desired.

Explanations are given of the reasons why the applicant for test must assume all risk of breakage, either in shipment or test. The circular contains general instructions to applicants for test, including instructions for packing and shipping thermometers, and the schedules of fees for testing.

General information on thermometry and temperature measurements, which was included in the previous edition of the circular, is to be incorporated, together with much new material, in a scientific paper entitled "Thermometry."

THE USE OF THE ULBRICHT SPHERE IN THE MEASUREMENT OF REFLECTION AND TRANSMISSION FACTORS.[5]

By Enoch Karrer.

[ABSTRACT.]

A BRIEF historical survey is given of the methods and instruments used in measuring the reflection factor of surfaces. Methods involving the use of the sphere are numerous. The various ways in which the sphere has been used up to recent years are briefly described. The recent applications of the sphere in a manner that affords the absolute determination of the reflection factor are also described, and several new ways of using the

[5] Scientific Paper No. 415.

sphere are pointed out. One of the new ways is given in some detail. It consists in a combination of the sphere with the Martens polarization photometer. The Martens polarization photometer enables a direct comparison to be made between the brightness of the sphere wall and the brightness of the test surface which closes an aperture in the sphere. The sphere wall is illuminated by directing a narrow beam of light through an aperture on to a spot of the sphere walls adjacent to the aperture that is closed by the sample. The sample is illuminated by the sphere wall, but is screened from the direct light from the illuminated spot. The ratio of brightness which is obtained by means of the Martens photometer is exactly the reflection factor of the test surface.

Thus the reflection factor is determined by one observation without further calculation, and without the use of a standard reflecting surface. This method may be modified so that the transmission factor may likewise be determined absolutely. The theory of the hollow sphere (commonly referred to in technical literature as the Ulbricht sphere) is given to show how this reflectometer in theory and practice conforms with it. The use of the sphere in some such manner as this is a step toward standardization.

Since the reflectometer described above resembles somewhat an instrument designed for the same purposes, but based upon the principle of the infinite luminous plane, the theory of the infinite plane is given. Sufficient discussion is given of the actual application of the theory in case of the Nutting reflectometer to show that the simple theoretical conditions are not at all attained. It is pointed out how two concentric spheres may be used instead of infinite planes.

A simple and inexpensive reflectometer is also described that may be of service for certain commercial purposes where an accuracy of 10 to 15 per cent. is allowable.

Some data are given to show that the reflection factor of magnesium carbonate in blocks as frequently used in photometry is as high as 98.7 per cent., corroborating some recent determinations by others. The value for magnesium carbonate has until recently been assumed to be 88 per cent. All blocks of magnesium carbonate as ordinarily purchasable have not as high a reflection factor. They may vary by several per cent.

SPECIFICATIONS FOR FIRE HOSE.[6]

[ABSTRACT.]

THIS specification was drawn up by the Bureau of Standards for use by government departments. The specification was submitted to the Rubber Association of America and has received the official endorsement of the Technical Committee on Specifications.

The hose purchased under the requirements of this specification is cotton rubber lined hose. The types of hose included are single-jacketed hose for use at fire hydrants, stand-pipes, and similar places, and double- and triple-jacketed hose for use on pumping engines and in places where additional wear requires increased protection afforded by the extra cotton jackets.

The chemical and physical tests to which the hose must conform are described in detail. The requirements for the rubber lining are: (1) It shall contain at least 75 per cent. by volume of the best quality new wild, or plantation rubber. (2) The organic acetone extract shall not exceed 5 per cent., and the total sulphur 8 per cent. of the weight of the rubber as compounded. (3) Its tensile strength shall be at least 1600 lb. per sq. in., ultimate elongation at least 500 per cent., and set not more than 25 per cent. after a stretch of 400 per cent. for 10 minutes after 10 minutes' rest. (4) Its lap must stand a minimum pull of 75 lb. per linear inch. (5) Its tensile strength shall be not less than 900 lb. per sq. in. after heating for 96 hours at 158 ± 2° F., in order to determine the probable aging qualities.

The strength of the cotton jacket is insured by the requirements for certain measurements to be made on the finished hose when under hydraulic pressure. These measurements consist of determining the amount of elongation, twist, warp from a straight line, rise from the ground, kink and bursting pressure.

The brass couplings are governed by the requirements as to the composition of the alloy.

THE STRUCTURE AND RELATED PROPERTIES OF METALS.[7]

[ABSTRACT.]

THIS circular, which supplements one of earlier date entitled "Metallographic Testing," is a comprehensive discussion of that

[6] Circular No. 114

[7] Circular No. 113.

phase of the subject of metallography which is indicated by the above title. With but very few exceptions, the numerous illustrative examples which have been used throughout the text as types have been taken from the results of examinations of metallographic specimens submitted to the Bureau of Standards for examination and test.

In the discussion of the methods for revealing the structure of metals, the various reagents used in the macroscopic study of metals are described particularly as related to the purpose for which they are used, that is, for revealing chemical unhomogeneity, crystalline heterogeneity, physical unsoundness and mechanical non-uniformity. The principles underlying the action of etching reagents are discussed, and a list of suitable reagents for revealing the microstructure of the common industrial metals and alloys given.

Chief among the conditions which affect the structure of an alloy is chemical composition, and for any particular stystem of alloys this is graphically summarized in the constitutional or structural diagram. The structure is also profoundly affected by temperature, for example, upon heating, an alloy tends to assume a condition of physico-chemical equilibrium by diffusion, etc., so that after heating, the structure may be profoundly different from the initial state. Grain growth and phase changes upon heating are also of importance, particularly the latter, as it is to this property that the value of heat treatment as a means of obtaining wide variations in the physical properties of steel and other alloys is due. The mechanical deformation which constitutes the "working" of a metal also has a decided effect upon the structure of a metal.

In the discussion of the effect of structure upon properties, the mechanical and the chemical properties are emphasized. Some of the factors discussed which affect the mechanical properties are the presence of both hard and soft constituents such as occurs in a host of alloys, the effect of soft ductile constituents, the effect of the orientation of a test specimen with respect to the material under test, the effect of grain size, and also the physical state of any particular microscopic constituent. Typical applications of the microscopy of metals are discussed under the following heads: Relation to heat treatment, as a supplement to chemical analysis,

for controlling various metallurgical operations and products, as a necessary aid in the construction of constitutional diagrams of alloys systems, as a means for supplying important evidence bearing on the failure of metallic materials in use and on the service deterioration of certain types of alloys.

The nature of the metallurgical tests and investigations for which the Bureau of Standards is equipped is also briefly discussed.

PREPARATION OF GALACTOSE.[1]

By E. P. Clark.

[ABSTRACT.]

In preparing galactose 1500 g. of lactose are dissolved in 3750 c.c. of hot water containing 75 g. of concentrated sulfuric acid. The solution is brought to a boil and then simmered for two hours. A thin paste of barium carbonate is then added to the hot solution until it reacts neutral to Congo paper. The precipitate of barium sulfate is allowed to settle over night, after which as much as possible of the supernatant liquid is drawn off. This liquid is filtered through a thin layer of active carbon placed on moistened filter paper in a Buchner funnel. When all has passed through, the precipitate is placed on the filter, drained as dry as possible, and finally washed by drawing a little water through it. The filter, prepared with a small amount of carbon, as outlined, clarifies the solution and at the same time prevents the sulfate from passing through and gives a relatively rapid filtration.

The filtrate is concentrated under diminished pressure until it has a weight of 1650 g. If a refractometer is available the concentrated syrup should have a refractive index between 1.5120 and 1.5125. The very thick syrup is warmed to between 60 and 70° C. and 250 c.c. of ethyl alcohol are dissolved in it by vigorous shaking. The solution is then poured into a beaker or jar and the remaining syrup is washed from the flask with 500 c.c. of methyl alcohol this is done best by adding the methyl alcohol to the flask portionwise, warming and shaking in a water bath. The whole solution is thoroughly mixed, seeded with some pure galactose crystals, and allowed to crystallize.

[1] Scientific Paper No. 416.

The crystallization is generally complete in about four days, after which the galactose is filtered off, washed with a little methyl alcohol, then with 85 per cent. ethyl alcohol, and finally with 95 per cent. alcohol. It is then dried. The yield of this crude sugar is about 27 per cent. of the lactose taken.

In order to purify the crude galactose, it is dissolved in water, making about a 25 per cent. solution. To this is added a few c.c. of glacial acetic acid. It is then concentrated under diminished pressure to about 75 per cent. total solids, warmed to 60 or 70° C., transferred to a beaker and 95 per cent. alcohol added to saturation. Almost immediately the contents of the flask become solid. After allowing to stand over night, it is filtered from the mother liquor, washed and dried. The yield is generally 82 to 83 per cent. of the crude sugar taken.

THE SPECTRAL DISTRIBUTION OF ENERGY REQUIRED TO EVOKE THE GRAY SENSATION.*

By Irwin G. Priest.

[ABSTRACT.]

THE need of a rigidly defined standard of "white light" has long been felt, the only such "standards" in use being more or less arbitrary and without agreement among themselves. In order to be accepted as such, a standard of white light should be described in terms of the Planckian distribution of energy required to evoke the hueless sensation of brilliance commonly called "white" or "gray." Although a number of incandescent solid sources approximate in their spectral distribution of energy to the condition imposed by this formula, no source can be raised to a sufficiently high temperature to produce the sensation of white. The problem is not impossible of solution, however, for means have been found by which the spectral distribution of a source can be modified so that the distribution among the wave-lengths in the visible spectrum can be made to assume the form required by Planck's formula, for any temperature from 4000 to 7000° K, inclusive. This is accomplished by means of rotatory dispersion, produced by a system of nicols and quartz plates.

* Scientific Paper No. 417.

In this way a stimulus is obtained that will satisfy the most rigid requirements. The next step is to develop a suitable method from the subjective standpoint, that is, certain conditions must be satisfied under which the observer determines which ones of a given set of stimuli evoke in him the sensation of white. The chief factors are the following:

1. Fatigue effects must be avoided, by resting the eyes in the dark fully ten minutes before making observations, and by avoiding stimuli of too high or too low intensity.

2. The field of view should subtend at the eye an angle of at least 3.5° for clear vision.

3. The background should be dark, in order to avoid contrast effects.

4. The judgments should be made quickly, before the eye feels the slightest fatigue.

As the spectral distribution of the source is changed to conform with that required by the Planck formula for temperatures from 4000 to 7000° K, the color changes from yellow to white and then to blue. A suitable choice is made of six temperatures covering the transition interval from yellow to blue. The operator sets the instrument for one of these temperatures, then signals the observer to open his eyes and pronounce his judgment on the color evoked. In this way a hundred answers for each temperature have been obtained from each of four observers.

The results are shown graphically, the probability of choice as blue, white, or yellow being plotted as a function both of the (hypothetical) temperature of the source, and of the centre of gravity of the light-distribution curve corresponding to that temperature.

Another method was tried by one observer, that of changing the setting rapidly from blue to yellow or *vice versa,* in order to find the setting for white. This method involves a change in intensity of the stimulus, and is not so satisfactory as the other method.

On account of the small number of observers involved, no general conclusions can be drawn from the data obtained. The results of one observer are different from those of the other three, due perhaps to a defect in the cornea, or a decided difference in visibility, or a difference in age. The conclusion to be drawn from the observations of the other three is that the hypothetical

temperature of the source (conforming to the Planckian energy distribution) that evokes the sensation of gray is about 5200° K. The centre of gravity of this light distribution is 560.4 millimicrons, or approximately the same as average noon sunlight. The results are compared with previously proposed standards for average daylight.

This investigation can be regarded only as preliminary, due to the small number of observers concerned. But the "method of answers" has been demonstrated as perfectly reliable, and there seems no reason why, with a greater number of observers, the problem of a standard of white may not be solved.

SPECTRORADIOMETRIC INVESTIGATION OF THE TRANSMISSION OF VARIOUS SUBSTANCES, II.[10]

By W. W. Coblentz.

[ABSTRACT.]

THIS paper gives transmission data in the spectrum extending from 0.6μ to 3μ, using a mirror spectrometer, a quartz prism and a vacuum thermopile. The substances examined are a group of mineral, animal and vegetable oils (containing fatty acids), nitrocellulose, bakelite and selenite. It is shown that the absorption spectra of the oils are so nearly identical that they cannot be used for detecting the adulteration of one oil with another. The paper concludes with an examination of the accuracy of the author's previous work, using a rock salt prism. It is found that, using the recently determined refractive indices of rock salt, the corrections to the observations of 1903 to 1905 are of the order of 0.01μ to 0.02μ and hence negligible.

THE DESIGN OF ATMOSPHERIC GAS BURNERS.[11]

By Walter M. Berry, I. V. Brumbaugh, G. F. Moulton and G. B. Shawn.

[ABSTRACT.]

THE Bureau of Standards has carried on an extensive investigation of gas burner design, intended primarily for the benefit of manufacturers of gas appliances and industrial gas appliance

[10] Scientific Paper No. 418.

[11] Technologic Paper No. 193.

engineers. No extensive presentation of theory has been attempted, the aim being rather to show by means of tables and curves, representing experimental data, the effect of the various factors on the operation of burners.

With the arrangement of apparatus and method of testing that has been developed one can measure quickly and accurately the volume of air injected into any burner under any condition of operation, as well as determine the limits of operation with any quality of gas. Such information is essential in order to enable one to design burners for any predetermined condition of operation.

In order to understand the various factors entering into the design of burners it was found necessary to study the theory of flow of gas through different types of orifices, the principles governing the rate of injection of air into the burner, the design of the injecting tube, the rate of consumption of burners of different port areas, and the effect of adjustment of the air shutter.

THE ORIFICE.

The orifices have been divided into two classes—the "channel" type, which has some thickness between the inner and outer wall at the point of discharge, and the "sharp edge" type, in which the inner and outer walls come to a sharp edge at the point of discharge.

1. *Discharge Coefficient of Orifices.*—The discharge coefficient of a sharp edge orifice with a given angle of approach is a constant for ordinary sizes of gas orifices and over the usual range of gas pressures. When the discharge coefficient was determined for sharp edge orifices with different angles of approach it was found that it varies from about 0.605 for a 90° approach to about 0.875 for an 8° approach.

It was found that with orifices of the channel type the coefficient will vary not only with a change in the angle of approach but also with a change in the length of channel and the pressure of the gas.

2. *Loss of Air Injection with Different Types of Orifices.*—With the sharp edge types of orifices the friction loss was found to be exactly the same for all designs. The friction loss of the channel type varies with the length of channel and is greater than the friction loss of the sharp edge type.

3. *Rate of Flow Through Orifices.*—If the rate of flow of gas through an orifice is desired, or the size of orifice is required for any given gas rate, it is necessary to know the gas pressure, the specific gravity of the gas, and the discharge coefficient of the orifice. The following formulas will enable one to calculate readily any one unknown value by substituting in the formula the known values.

$$Q = 1658.5\ KA\sqrt{\frac{H}{d}} \text{ or } A = \frac{Q}{1658.5\ K}\sqrt{\frac{d}{H}}$$

where Q = rate of flow through orifice in cubic feet per hour;
A = area of orifice in square inches;
K = orifice constant, or discharge coefficient;
H = orifice pressure in inches of water;
d = specific gravity of gas (Air = 1.0).

PRINCIPLES GOVERNING AIR INJECTION.

From the fundamental theory and the relations which have been illustrated by examples it is possible to summarize the most important relations as follows:

1. The ratio between the momentum of the gas stream and the momentum of the stream of the mixture is always the same for a burner of a given design irrespective of orifice pressure, specific gravity of gas, or the volume of the air and gas mixture going through the burner.

2. Where the gas rate is increased by change of pressure, the momenta of the gas streams are directly proportional to the pressures.

3. When the same volumes of gases of different specific gravities issue from different orifices under the same orifice pressure the momenta of the gas streams are proportional to the square roots of the specific gravities of the gases.

4. When the pressure is changed to give the same gas rate for gases of different specific gravities, the air entrainment is proportional to the specific gravities.

5. The pressure at any one point in the burner increases in direct proportion to the increase in the momentum of the stream of the mixture.

If the volume of air injected into a given burner for a gas of a given specific gravity at a given pressure and the gas rate is known, it is possible to calculate from the above stated relations

the volume of air injected with a gas of any other specific gravity, gas rate, or gas pressure.

THE INJECTING TUBE.

The advantages of using an injector of good design to increase the injection of primary air has been illustrated by tables and a large number of curves. The general design of an injecting tube that produced the greatest injection of primary air was determined. If it is impracticable to use injectors of the best design because of limitations in the size of the burners, it is possible to determine from the tables and curves which are given the relative injecting power of other designs.

It is very important that there should be a definite relation between the area of the throat of the injecting tube and the port area of the burner if the energy of the gas is to be efficiently utilized to inject air into a burner. The results of the tests show that the area of the injector throat should be about 43 per cent. of the area of the burner ports.

BURNER TUBE AND BURNER PORTS.

In the section on the burner tube the characteristics required in a satisfactory burner have been discussed. For burners without injecting tubes it has been shown how the rate of consumption per square inch of port area increases with increase in the port area. The rate of consumption of burners with injecting tubes has been shown in the same way. From the tabulations and curves the rate of consumption per square inch of port area corresponding to an average burner has been determined, and tables have been prepared which show the rate of consumption of various sizes of burners for different gas pressures.

THE AIR SHUTTER.

The velocity of the air through the air opening will depend upon the area of the air opening, the momentum of the gas stream issuing from the orifice, the area of the burner ports, and the design of the injector. For the greatest injection of air the opening in the air shutter must be large enough to allow a free and unrestricted flow of air into the burner. From a few curves that have been shown it seems that the area of the air opening should be of such size that the velocity of the air through the opening does not exceed 4 or 5 ft. per second.

CONCLUSION.

On account of its simplicity, low cost, and reliability the atmospheric burner is well adapted for domestic and most of the smaller industrial purposes. If it is possible to widen the range within which such burners can be operated efficiently and without adjustments, and design them to meet the needs of any particular purpose, it will make gas fuel much more valuable and will broaden its field of application. With this in view the Bureau of Standards has been conducting experiments upon the efficiency and performance of atmospheric burners, both with natural and artificial gas, and the results will be reported in subsequent papers.

HIGH FIRE PORCELAIN GLAZES.[13]

By H. H. Sortwell.

[ABSTRACT.]

THIS work consists of the investigation of a wide range of high fire porcelain glazes of the Seger cone formula type to determine the limits wherein lie glazes suitable for high fire porcelain, chemical porcelain, spark plugs, pyrometer tubes, etc., maturing at temperatures of from Seger cones 12 to 16. The field was studied from the standpoint of fusbility and of commercial acceptability as glazes.

Compositions Studied.—The RO of all of the glazes was maintained constant at 0.7 equivalents CaO and 0.3 equivalents K_2O. The variations were in the SiO_2 and Al_2O_3 contents, the SiO_2 varying from 3.0 to 13.0 equivalents and the Al_2O_3 varying from 0.3 to 3.25 equivalents between the alumina : silica ratios of 1 : 4 and 1 : 20. This covered the field with fair uniformity when plotted both by empirical formulas and by batch weights.

Methods Employed.—The glazes were weighed separately and ground in small ball mills three hours. A small quantity of each glaze was evaporated to dryness and moulded into test cones. The deformation temperatures of the cones were determined in a small gas furnace. Check determinations were made to within 5° C. The temperature was raised at the rate of 50° C. an hour above 1100° C.

[13] Technologic Paper, No. 196.

The glazes were applied to porcelain cups which had been biscuited to cone 08. The composition of the body was 31 North Carolina kaolin, 12 Florida kaolin, 5 Tennessee ball clay, 34 flint and 18 feldspar.

Four glaze burns were made in a gas-fired kiln, to cone 10 in 20 hours, to cone 12 in 20 hours, to cone 14 in 22 hours, and to cone 16 in 24 hours. Reducing conditions were maintained to cone 8, but from that point allowed to diminish until the fire was neutral or slightly oxidizing at the finish.

Deformation Temperatures.—The deformation temperatures of the glazes were from 1100° C. to 1400° C. The fusibility of the entire field is shown graphically by isotherms, plotted both by empirical formulas and by batch weights.

There is a deformation eutectic axis lying at a slight inclination to the ordinate representing Al_2O_3 between 0.55 and 0.60 Al_2O_3, up to 7.0 equivalents of SiO_2. As the SiO_2 content approaches 7.0 equivalents this inclination rises and at 11.0 equivalents silica it increases much more.

Starting with 0.3 Al_2O_3 and any SiO_2 content increasing the Al_2O_3 lowers the deformation temperature until the deformation eutectic axis is crossed. Further increase in Al_2O_3 increases the deformation temperature.

Increase in silica content up to 11 equivalents has little effect in comparison with Al_2O_3 in increasing the deformation temperature. Beyond this figure further increase in SiO_2 increases the deformation temperature more rapidly.

Glaze Burns.—At cone 10 the number of good bright glazes is comparatively small and they are surrounded successively by semi-mat, mat, and immature glazes. Crazing occurs when the alumina content of the glazes is low.

Increase in the burning temperature increases the number of good bright glazes, causes a proportionate shift in the location of semi-mat and mat glazes and reduces the number of immature glazes. With increase in burning temperature, the occurrence of crazing is reduced. Overburning occurs in the more fusible glazes as the temperature increases.

Increase in Al_2O_3 in this type of glaze corrects crazing. Increase in SiO_2 will not correct crazing, but if increased sufficiently may cause it to occur.

The best glazes are higher in Al_2O_3 content than the most fusible glaze with the same amount of SiO_2. The most fusible glazes with a given silica content above 7.0 equivalents craze.

The results of the glaze burns are plotted graphically showing the location of the best glazes at the different temperatures, the location of mat and semi-mat glazes and the occurrence of crazing.

There is a wide range of commercially acceptable bright glazes of this type with a heat range of from 4 to 5 cones. The best glazes for cones 12 to 16 with the RO of 0.7 CaO and 0.3 K_2O fall under the approximate formula:

$$Al_2O_3 = 0.3 + 1/12\ Si\ O_2$$

The fusibility may be controlled by varying the SiO_2 from 4.0 equivalents for cone 12 to 10.0 equivalents for cone 16, with the Al_2O_3 content indicated by the formula.

STANDARD SPECIFICATIONS FOR LARGE INCANDESCENT ELECTRIC LAMPS.[13]

[ABSTRACT.]

FOR about fourteen years electric lamps have been purchased by the Federal Government under specifications published in Circular 13 of the Bureau of Standards. Progress in the art of lamp manufacture has been so rapid that this circular has to be revised eight times in order to keep the specifications abreast of current developments. The original specifications covered only carbon filament lamps. In later editions metallized carbon and tantalum lamps were introduced and then discarded, as tungsten filament lamps gradually displaced them in use. In connection with these radical changes in types of lamps, very great improvements were made in the efficiency and the life required, but no fundamental change was made in the form of the specifications or in the methods of testing.

For the fiscal year beginning on July 1, 1921, new specifications have been adopted, which include important changes in the test procedure for tungsten lamps.

The most notable of these changes is the abandonment of the long-established provision that the life of test-lamps shall be considered as ended when the candlepower has fallen to 80 per

[13] Circular No. 13, (9th edition).

cent. of the initial value. The specification of such an end-point is convenient and reasonable in the testing of carbon lamps because those lamps will often burn for a long period after they have become so blackened that they should not be continued in use. In tungsten lamps, however, means have been found to prevent excessive blackening of the bulbs, so that the lamps normally burn out before their efficiency has fallen enough to justify replacing them. The new tests will therefore be based on the total life to the time of burn-out, thus conforming more nearly to actual practice in the use of lamps.

The performance of the lamp throughout its life will also be taken into account through two new provisions. One of these is the evaluation of life-test results on the basis of average efficiency throughout life, instead of the initial efficiency; the other is a requirement that the average light flux during the life of the lamp must not fall below a specified percentage of the initial flux.

Another new feature is the establishment of tolerances to allow for possible variations in test results arising from the fact that small numbers of test samples may not represent fairly the average quality of the lamps from which they are selected.

On account of the desirability of standardizing a small number of voltage ratings, the tungsten lamp schedules recognize specifically only the five- and ten-volt steps instead of the former voltage ranges. It is understood that for the present lamps of other voltages within the usual range will be furnished under the same specifications, but users will ultimately find it advantageous to bring their circuits to one of the standard voltages.

Tests under these new specifications are intended to give a more complete indication of the performance of lamps than the former specifications did, and thus to discriminate more exactly between types of lamps. In the first application of the new specifications it has, however, been deemed wise to make the requirements moderate. The numerical values in the tables of requirements are based on extensive studies of the performance of lamps in tests made by various manufacturers as well as by the Bureau of Standards. It is believed that they have been so adjusted that the change in specifications will involve no injustice either to lamp manufacturers or to purchasers. The carbon-lamp schedule has been retained because these lamps still find some use,

but the specifications for them are practically unchanged from those given in previous editions of this circular.

These specifications have been prepared primarily for the use of the departments of the government in purchasing incandescent lamps, but it seems desirable, on account of the thoroughness with which the subject has been studied and discussed, that the specifications should be available to the general public. They are, therefore, being issued as the ninth edition of Bureau of Standards Circular No. 13, and copies may be obtained on application to that Bureau. Criticisms and suggestions concerning these specifications and lamp ratings are invited from both manufacturers and users of lamps. All such suggestions will be carefully considered when the specifications are again revised.

A Reciprocating Apparatus for Detecting Ionizing Rays. TAKEO SHIMIZU. (*Proc. Roy. Soc.*, A. 700.)—Mr. C. T. R. Wilson, of Cambridge, years ago devised a very elegant method of making visible the paths of ionizing particles in gases. Air containing water vapor was expanded suddenly and the vapor condensed upon the ions. The path of an alpha particle was a streak of cloud, the droplets of which had formed around the ions caused by the collisions of the particle. Mr. Shimizu has modified the method so that the expansion is produced twice a second along with the application of an electrostatic field for a known part of the stroke. A reciprocating mechanism operates the piston governing the expansion.

For a study of the path of each track the Wilson apparatus is superior. It is, however, claimed that the newer form is more sensitive and by the periodic recurrence of the stroke it is possible to study the time of the origination of the rays producing the traces.

Mr. Shimizu has used his device to investigate the products of collisions with alpha particles. Sir Ernest Rutherford states that among 100,000 alpha particles from radium C passing through air there will be one making close collision with an atomic nucleus so as to produce a rapidly moving atom. A moving picture film recorded the tracks as seen from two positions at right angles to each other. In the 3000 tracks photographed 35 spurred tracks were found, but their explanation and interpretation remains for the future.

Owing to this recently devised apparatus it has thus become possible to have a registration at half-second intervals, if not continuously, of what goes on in air subject to the bombardment of ionizing particles. This field of investigation is thereby advanced to an extent comparable to the progress introduced into other fields upon the employment of continuously recording methods.

G. F. S.

NOTES FROM THE LABORATORY OF APPLIED SCIENCE, NELA RESEARCH LABORATORIES.*

RHYTHMIC DEPOSITION OF PRECIPITATED VAPORS.[1]

By E. Karrer.

[ABSTRACT.]

RHYTHMIC deposition of ammonia hydrochloride is observed when ammonia and hydrochloric acid vapors are allowed to mix by diffusion. Good results are obtained when the vapor of ammonia diffuses into the vapor of hydrochloric acid contained in rather small vials which are well protected from ordinary atmospheric disturbances. The rhythmical deposits in such vials may be separated by more than a centimetre or by only a fractional part of a millimetre. In fact, the fineness of the resulting laminar structure may almost go beyond that detectable by the unaided eye. Observations are recorded which show that a temperature-gradient laterally is necessary. The phenomenon is very closely related to that recently studied by Mendenhall and Mason, who showed that the striæ in sedimentation are brought about by the convection currents in the liquid resulting from a lateral temperature-gradient. It is also pointed out that the stratification in gases may be of importance in meteorology as is the stratification of sediment in geology, and as is the Liesegang phenomenon, *i.e.*, rhythmic precipitation in gels, in biology.

The stratification of gases frequently observed by gas engineers, both in large as well as in small containers, may be referable to this phenomenon.

THE SHAPE ASSUMED BY A DEFORMABLE BODY IMMERSED IN A MOVING FLUID.[2]

By E. Karrer.

[ABSTRACT.]

GENERAL considerations are given of how a deformable body will change its shape in a moving fluid. On certain phases of this question considerable work has been done in aeronautics; as for

* Communicated by the Director.

[1] To be published in the *Jour. American Chemical Society.*

[2] To be published in this Journal.

example, the resistance encountered by a body of definite shape when moving in air or water; and the distribution of pressure over the surface of the body when moving in air (wind-tunnel experiments).

The theme of the present work is that a body, immersed in and in relative motion with a fluid, will assume as nearly as possible a shape such that contour lines are stream-lines. Observations on a mercury drop are given to substantiate this theme. Illustrations are also gathered from many realms of science—geology, biology, physics, meteorology.

In biology the importance of the adjustment of shape to stream-line contours seems sufficiently great to be designated by a term (rheotropism), for this phenomenon is parallel to others where the organism adjusts itself to a field of directed stimulus, as geotropism, heliotropism, and galvanotropism.

COMMENTS ON THE THEORY AND PRESENT STATUS OF FLICKER PHOTOMETRY.

By A. H. Taylor.

[ABSTRACT.]

THE flicker photometer has been used to some extent in heterochromatic photometry, to avoid the difficulties usually encountered in photometering lights differing greatly in color. However, its more general adoption has probably been retarded by a lack of understanding of its theory, and by practical difficulties encountered in its operation. This paper gives a simple treatment of the theory from a new point of view, and gives references to published data bearing upon it. It also points out some requirements for satisfactory operation of such photometers. Full details will soon be available in the *Transactions of the Illuminating Engineering Society*.

PAINTS FOR INTEGRATING SPHERES.

By A. H. Taylor.

[ABSTRACT.]

MANY photometric integrating spheres for measurement of light flux are in use in this country, but considerable difficulty

has been encountered in obtaining a satisfactory white paint which was tenacious and permanent in color. An investigation carried out by the author at the Bureau of Standards several years ago resulted in a very satisfactory paint. The formula for the paint, together with full details as to preparation and use, will soon be published in the *Transactions of the Illuminating Engineering Society*.

CLEVELAND, OHIO,
August 16, 1921.

Stereoscopic Portraits.—*Das Atelier des Photographen* has an article on this subject, referring to an invention made in 1853, by a Philadelphian, J. F. Mascher, who took out a patent in that year for an "Improvement in Daguerreotype Cases." The main feature of his invention was the provision of a small convex lens attached in a movable flap to the case containing the picture so that it could be viewed somewhat magnified, but the special feature was the making of two portraits by stereoscopic methods and providing a pair of lenses for securing the effect. The German writer figures the apparatus, and states that the pictures show an exaggerated solidity, and were probably made by a collodion film on glass, being, therefore, of the nature of the ambrotype, which was much in vogue prior to the introduction of the paper positive. A picture of the apparatus is given. It is interesting to note that one of the stereoscopic portraits is in the possession of The Franklin Institute. It was evidently made by a stereoscopic camera, for the two pictures have noticeable, though slight, differences and when viewed with the lenses show a strong, indeed excessive, solidity. The claim in the patent does not specifically refer to the application of stereoscopy, and the inventor put on the market many cases with single pictures. The attention given to the matter indicates that the Germans, like the French, are taking much interest in the revival of stereoscopic work, a special field which has been the subject of a good deal of discussion lately in the projection on the screen of the effect of solidity.

H. L.

The Manufacture of Optical Glass.—This problem has received a great deal of attention of recent years. The dependence of the world at large upon Germany for glass suitable for the construction of many optical instruments for warfare and research was brought to notice when the war broke out, and it became necessary for the other belligerent nations to establish industries for the purpose. The subject is revived by the publication of a pamphlet by the Goerz Company, being a reprint of an article by Dr. F. Weidert (of the

Goerz Company) originally appearing in a Berlin engineering journal. The article is illustrated with eight full-page plates, giving views of certain parts of the factory of that firm. The title is "Herstellung und Eigenschaften des Optischen Glasses." One point of interest is the statement that just before the breaking out of the war, only three establishments capable of producing optical glass existed. These were: Chance Brothers in England, Parra-Mantois in France and Schott and Company in Jena. The product of the English firm was principally for mirrors, of which it was the largest European manufacturer, but its true optical glass was in small amount. The Paris firm produced a high-class material but not in large amount. The Jena firm was not deemed sufficient for the needs of Germany, and shortly before the war another German establishment was founded. The pamphlet gives an account of the principal features of the establishment of the German glass industry, in which the familiar names of Steinheil and Fraunhofer appear. H. L.

New Determinations of the Density of the Air at Geneva. A. TREUTHARDT. **On the Density of the Air at Madrid and its Slight Variations.** MOLES, BATUCCAS AND PAYA. (*Comptes Rendus,* June 20, 1921.)—Contrary to the general belief the density of the air under standard conditions is not strictly constant. At the same place it appears to be less by some tenths of a milligram per liter during periods of high barometric pressure. This was shown to true for the air of Geneva by Guye and his collaborators in 1910, and was confirmed two years later for the same place and six years later for Cleveland, Ohio. Near a pressure of 760 mm. flasks were filled with air at zero from which water vapor and carbon dioxide had been removed. The previous results were confirmed by the Swiss as well as by the Spanish observers. The latter plotted both the changes in barometric height and in density for considerable part of a year. It is noteworthy that when one of these changes increases the other decreases almost unfailingly. At one period of apparent exception to this statement the weather was clear and the sunshine strong. This led to the suspicion that ozone might be the cause of the divergence. When the air was treated in such manner as to free it from ozone its density was found to cease to be exceptional.

The average of the determinations in Geneva was 1.29269 per liter and in Madrid 1.29303. In view of the outcome of the experiments it is suggested that air should not be used as a standard for getting the densities of other gases.

The quantities concerned are, to be sure, small, but let it be remembered that other minimal differences of density led to the discovery of argon.

G. F. S.

NOTES FROM THE RESEARCH LABORATORY EASTMAN KODAK COMPANY.*

A CRITIQUE OF MR. RENWIK'S THEORY OF THE LATENT IMAGE.[1]

By S. E. Sheppard.

[ABSTRACT.]

MR. F. F. RENWICK has proposed a theory of the latent image according to which developability is due not to a photochemical decomposition of the halide, but to the coagulation by light of preëxistent colloidal silver nuclei (due to ripening) to coarser-grained nuclei capable of functioning as development germs. In the criticism it is pointed out that experiments on the direct action of light in lowering the dispersity of colloidal silver in aqueous solutions do not lend support to this hypothesis, as the sensibility does not seem sufficient. It is argued that a photochemical development of the original nuclei by decomposition of the silver halide is essential, and the function of colloid silver as a specific photochemical autocatalyst for this photolysis is discussed.

THE SIZE-FREQUENCY DISTRIBUTION OF PARTICLES OF SILVER HALIDE IN PHOTOGRAPHIC EMULSIONS AND ITS RELATION TO SENSITOMETRIC CHARACTERISTICS.[2]

By E. P. Wightman and S. E. Sheppard.

[ABSTRACT.]

C. E. K. MEES, in a paper on "The Physics of the Photographic Process," had pointed out the possibility of a relationship between size-frequency of grains in a photographic emulsion and the characteristic D-log E curve for that emulsion. The relations suggested, however, were speculative.

Experimental work was begun on the problem in 1919. In the meantime Slade and Higson, and T. Svedberg have published

* Communicated by the Director.

[1] Communication No. 113 from the Research Laboratory of the Eastman Kodak Company, published in *B. J.*, Jan. 7, 1921, p. 4.

[2] Communication No. 103 from the Research Laboratory of the Eastman Kodak Company, published in *J. Phys. Chem.*, March, 1921, p. 181.

some work along the same line. The former believe that γ infinity is increased by homogenizing the grain and that latitude is diminished. The latter, working with dilute emulsions one-grain layer thick, obtained (a) curves connecting exposure and percentage reduced grains for each order of magnitude of the grains, (b) curves showing the relation between size of grain and percentage made reducible after a certain exposure. The first type of curve is comparable with the characteristic curve; the second gives the relation of light sensitiveness of size of grain. It appears from this work that every class of grain has its own characteristic curve.

The authors of the present paper have calculated the actual D-log E curves for the four classes of grains used by Svedberg by means of a relationship assumed by Higson to exist between the size of the developed grain and its photometric constant. The results of this calculation indicate a fallacy in Higson's assumption that the developed grain has twice the diameter of the original undeveloped grain. This is shown by a comparison of the summation curve of the values for each class size (based on the assumption that the developed grains in Svedberg's work were not twice, but approximately the same diameter as the undeveloped grain) with the experimental D-log E curve for the Svedberg emulsion. A size-frequency distribution curve plotted from Svedberg's data shows that by far the largest number of grains in his emulsion had a mean projective area less that 75 sq. mm. $\times 10^{-8}$.

COLLOIDAL FUELS, THEIR PREPARATION AND PROPERTIES.[1]

By S. E. Sheppard.

[ABSTRACT.]

THIS paper was given at the Fuel Symposium of the American Chemical Society Convention at Chicago, 1920. Applications of colloid chemistry to the fuel problem are discussed, and a description given of a new class of liquid and semi-liquid fuels. These were developed in the Laboratory in the last two years of the war, following a suggestion of Mr. J. G. Capstaff and in coöperation with the Submarine Defense Association, and consist

[1] Communication No. 101 from the Research Laboratory of the Eastman Kodak Company, published in *J. Ind. Eng. Chem.*, January, 1921, p. 37.

of various forms of finely divided carbon stably suspended in fuel oil. The application of Stoke's law is discussed, and also, the development of fixateurs or stabilizers from lime soap greases, the solvent and chemical peptization of coals, and methods of incorporation and testing. A summary of results in large scale marine and power house trials is given and a survey of the characteristics of the fuels in the direction of economizing oil fuel, then menaced by the German submarine campaign.

THE MEASUREMENT OF COLOR.[1]

By C. E. K. Mees.

[ABSTRACT.]

THE methods of measuring color fall into two distinct classes, according to whether we wish to measure the sensation of the color produced upon the observer or the means by which that sensation is produced. When we wish to study the finished product, we need to measure the sensation; thus, if we are manufacturing ribbons of a definite shade, a method of measuring and specifying that color is necessary. But if we are dyeing ribbon, we shall be doing it by means of dyes, and it is necessary to have a method of measuring the amount of coloring power which the dyes have. This should be done independently of the color which they produce upon the goods when they are finished and in terms which can be translated at once into the weight of dye which it is necessary to use.

When measuring the amount of material which produces the sensation of color, we must use analytical methods owing to the composite nature of the light with which we have to deal, while when we are dealing with the sensation of color produced, synthetic methods of measurements must be employed. The analytical instrument used for the measurement of the amount of material which produces a given color is termed the "spectrophotometer," and by means of it the curves of absorption of light by the dye can be obtained, and from those curves the amount of coloring matter present can be read directly.

The instrument for measuring the sensation of color produced is known as a "colorimeter." Various forms of colorimeters are

[1] *Jour. Ind. Eng. Chem.*, 1921, p. 729.

known, the standard instruments being those which depend upon the colors of the spectrum itself, defining the color of an object in terms of its dominant hue, corresponding to a given position in the spectrum. Any color may then be defined in terms of the spectral position of its dominant hue and of the amount of white light which must be mixed with the spectral color to match the color in question.

This form of colorimeter is suitable primarily for use in the laboratory, but for use in the works more rugged and simple instruments have been designed, the latest being a subtractive instrument designed in the research laboratory of the Eastman Kodak Company which is based on the use of colored wedges, each wedge absorbing one-third of the color of the spectrum, so that the three wedges are yellow, blue-green, and magenta in color, the yellow wedge absorbing the blue light, the magenta, the green light, and the blue the red light. When these wedges are placed over each other in pairs, they will match any color provided that the intensity is adjusted at the same time by the use of a neutral gray wedge which is supplied as the fourth wedge of the instrument. The instrument is made with a number of attachments according to the purpose for which it is required, so that colored solutions, colored glasses, or colored pigments can all be measured by suitable attachments. A modified form of the instrument has been designed for use in measuring vegetable oils and especially for use with cottonseed oil.

EXPERIMENTS ON SULFIDE TONING.[8]

By E. R. Bullock and (in part) D. S. Mungillo.

(I) *The Effect of Modification of Ordinary Indirect Sulfide Toning.*—In the well-known method of sepia toning which consists in bleaching a black-and-white print in a bath of ferricyanide and bromide solution and redarkening it in a bath of sodium sulfide solution, a great many variations were made in the concentration, time of action, etc., of baths and also in the composition of the baths as far as this seemed possible without altering the chemical composition of the final (toned) image. The purpose of the experiments being to observe the variation with conditions of the color change which occurs on converting a silver image sub-

[8] Communication No. 116 from the Research Laboratory of the Eastman Kodak Company, published in *Br. Jour. Photo.*, July 29, 1921, p. 447.

stantially into one of silver sulfide, all such variations as the addition of a mercury salt to the bleach bath or of Schlippe's salt to the darkening bath were omitted.

Prints on Special Velvet Velox and Artura Carbon Black were prepared under conditions standardized for each paper and giving a supply of somewhat fully developed prints of good gradation in each case. The standard procedure adopted as normal for the toning process was substantially that given in recent issues of the *British Journal Photographic Almanac*.

A number of variations in the toning procedure which were found to have no influence on the final tone are enumerated in a separate table. A tone somewhat more purple than normal—hence usually an improvement—is obtained by the use of a bleach (such as permanganate-chloride) which converts silver to silver chloride, or by a brief immersion of the bleached print in a one per cent. sodium carbonate solution immediately prior to sulfiding, or (to a greater extent) by both. A tone which deviates—under certain conditions very greatly—from the normal in the opposite direction of yellow is obtained by the use of a plain ferricyanide, a ferricyanide-chloride, or a ferricyanide-iodide bleach, by immersing in an iodide solution prior to darkening, by adding iodide to the sulfide bath, by using a (ye'low) polysulfide in place of ordinary (colorless) sodium sulfide, by using very dilute sodium sulfide solution as the darkening bath, or by having considerable hypo present in a somewhat (or very) dilute sulfide bath.

(II) *The Polysulfide Method of Direct Sulfide Toning.*—This method gives tones which are identical with those obtained with hypoalum, and which are considerably more purple therefore than those given by the standard method above. The preparation of a suitable polysulfide toning bath was described; and it was found that it is possible to accelerate the somewhat slow action of this bath, without affecting the tone obtained, by the addition to it of either potassium sulfocyanide or thiocarbamide.

The Effective Temperature of Certain Stars. NORDMANN AND LEMORVAN. (*Comptes Rendus*, July 11, 1921.)—The determination of the temperature is based on results obtained with the heterochrome photometer interpreted by a study of the distribution of intensity in the spectra of the stars. The absolute temperatures of 17 stars are given, ranging from 27,700° to a mere 3050°. The North Star is credited with 8200°. G. F. S.

The Principle of Projective Covariance. I. MAIZLISH. (*Phys. Rev.*, July, 1921.)—In terms of mathematics the principle means that the equations of this science are homogeneous in Minkowski variables, or that they are covariant with respect to four specified transformations. The author is able to derive some interesting conclusions from his premises. For instance, assuming that the wave-length for which the energy in a spectrum is a maximum to be a function of the absolute temperature alone he derives the known relation that the product of the wave-length and the temperature is a constant. Again, on the assumption that the mean kinetic energy of a perfect gas depends on the absolute temperature solely, he shows that the two are directly proportional. Even the laws of a vibrating string are readily derived from the principle. Such success in widely separated fields prompts the query, "How is it that such fine flour comes from the stones, when no suitable grain went into the hopper? May it not be that all the logical implications of the assumptions have not been clearly seen?"

It is claimed that the Principle of Similitude introduced by Tolman is only a special case of the general Principle of Covariance.

G. F. S.

The Value of the Surface Tension of Mercury when Surrounded by Different Gases. J. POPESCO. (*Comptes Rendus*, June 13, 1921.)—Stoeckle has shown that the surface tension of mercury decreases when the liquid rests in contact with any gas. The present investigator seeks to study the progression of this decrease. A large drop of mercury rests on a horizontal surface of polished steel. A simple relation exists between the surface tension and the vertical distance from the summit of the drop to its equatorial plane. It is from changes in this distance that changes in the surface tension are inferred. A bell jar of steel covered the drop which was observed by a cathetometer through a window. When there was a vacuum within the jar the surface tension was calculated to be 44.4 mg. per mm. Upon the admission of air the value rose to 51.13 at the beginning. As time passed it sank and after 24 hours it reached 42.55. Quite similar results were obtained with both ammonia and sulphurous anhydride. In both cases the initial values were higher than with a vacuum, a rapid decrease manifested itself during the first ten minutes and the final values attained were considerably less than in a vacuum, *viz.*—39.7 and 34.3, respectively.

When the surface tension was again measured in a vacuum after the mercury had been surrounded for a day by a gas, it was found to return to the original value. This indicates that some modification of the surface less permanent than a chemical change had taken place. The author suggests that the phenomenon is due to adsorption.

G. F. S.

NOTES FROM THE RESEARCH LABORATORY, GENERAL ELECTRIC COMPANY.*

THE REACTION BETWEEN TUNGSTEN AND NAPHTHALENE AT LOW PRESSURES.

By Mary R. Andrews and Saul Dushman.

In the presence of an incandescent tungsten filament at a temperature above 1500° K, naphthalene ($C_{10}H_8$) is decomposed into carbon and hydrogen, the carbon being taken up by the tungsten. The rate of diffusion of the carbon into the tungsten is, however, extremely slow at 1500° K, and it is only at temperatures of 2300° and above that it becomes more rapid than the rate of decomposition of naphthalene at the pressures used. These pressures varied from .1 to 3.0 bars. Consequently most of the experiments on this reaction were carried out with tungsten filaments at temperatures ranging from 2300° to 2600° K.

By measuring the hydrogen evolved and also analyzing the filaments at different stages of carbonization it was found possible to determine the change in conductance with increase in carbon content. It was observed that the conductance at room temperature decreases linearly, with increase in carbon content, to a minimum value which is about 7 per cent. of that of the original tungsten. The carbon content at this point corresponds to the composition W_2C (3.16 per cent. C.). Further carbonization causes an *increase* in conductance to about 40 per cent. of that of tungsten when the carbon content has reached 6.1 per cent., corresponding to the formula WC. On further addition of carbon the conductance remains constant, indicating that no higher carbides are formed.

These experiments were carried out under such conditions that the pressure of naphthalene vapor in the bulb containing the filament was maintained constant at any desired pressure, while the hydrogen evolved was pumped out and collected in a separate reservoir. Thus the pressure of hydrogen in the neighborhood of the filament was kept negligibly low. It was therefore possible to measure ϵ, the ratio between the number of molecules decomposed and the number striking the filament per unit of time. It

* Communicated by the Director.

was observed that the value of this ratio decreases rapidly at the beginning of carbonization and then remains practically constant during the period of formation of W_2C. The actual value of ϵ in this stage varies with the pressure of naphthalene from about .02 to .06. At the point at which WC begins to form ϵ drops rapidly to .01 or less and continues to decrease as the carbon content increases. It is hoped to obtain an explanation of this phenomenon in the near future.

It has been found that for filaments containing less than 3.16 per cent. carbon the resistivity-temperature curves lie parallel to the curve for pure tungsten. That is, the difference between the resistivity of a carbonized filament and one of pure tungsten is approximately constant at all temperatures up to 2400° K. This is an extension of Delinger's rule which was enumerated to cover only impurities in metals, whereas in this case the added material forms a compound with the metal.

The two carbides both decompose at about 2700° K with volatilization of the carbon, so that the conductance increases finally to the same value as that of the original tungsten filament.

Preliminary measurements indicate that the melting points of W_2C and WC are about 3150° K and 3050° K, respectively. Determinations of the characteristics of carbonized tungsten filaments are in progress. It is also intended to investigate in the same manner the reaction between other hydrocarbons and tungsten.

SEPTEMBER 19, 1921.

Diffraction of X-rays by Liquids. A. DEBIERNE. (*Comptes Rendus,* July 18, 1921.)—In the last decade of last century when X-rays were new attempts were made to get evidence that they acted as light does. Reflection, refraction, diffraction were sought but in vain. Now it is known that a crystal acts in respect to X-rays as a diffraction grating toward ordinary light. Debye has found diffraction of the rays and the present paper reports the obtaining of this effect in a different way. A narrow beam of X-rays was sent through a layer of liquid sufficiently thick to absorb a good part of it. A photographic plate set perpendicular to the beam was placed in its path, but was shielded from the direct rays by a lead screen. After several hours of exposure the plate showed a central part free from trace of action by the rays, surrounded by an aureole. In some cases two diffraction rings clearly marked were obtained. Among the liquids used were mercury, methyl iodide and benzene.

G. F. S.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

STUDIES IN NUTRITION IX: THE NUTRITIVE VALUE OF THE PROTEINS FROM THE CHINESE AND GEORGIA VELVET BEANS.[1]

By A. J. Finks and Carl O. Johns.

[ABSTRACT.]

THE isolated proteins obtained by coagulation with heat from either the Chinese or Georgia velvet beans are adequate for the normal growth of albino rats. Chinese velvet bean protein prepared by dialysis, however, whether or not cystine was added, failed to promote normal growth. The bean meal, on the other hand, cooked or autoclaved and supplemented with either cystine or casein, resulted in nutritional failure, manifesting itself in lack of growth, regurgitation, diarrhœa, and, ultimately, death. These results strongly suggest the presence of a toxic factor.

THE CHEMICAL COMPOSITION OF PEANUT OIL.[2]

By George S. Jamieson, Walter F. Baughman, and Dirk H. Brauns.

[ABSTRACT.]

A STUDY was made of the composition of two samples of peanut oil one pressed from Spanish type peanuts grown in South Carolina, the other from Virginia type peanuts grown in Virginia. The samples had the following chemical characteristics.

* Communicated by the Chief of the Bureau.

[1] Published in *Am. J. Physiol.*, 57 (1921) : 61.

[2] Published in *J. Am. Chem. Soc.*, 43 (1921) : 1372.

	From Spanish type peanuts	From Virginia type peanuts
Specific gravity, 25°/25°	0.9148	0.9136
Iodine number (Hanus)	90.1	94.8
Saponification value	188.2	187.8
Unsaponifiable matter (per cent.)	0.22	0.27
Acid value	0.12	0.03
Acetyl value	8.7	9.5
Reichert-Meissl number	0.27	0.21
Polenske number	0.12	0.29
Saturated acids per cent. (determined)	21.4[3]	17.4[4]
Unsaturated acids per cent. (determined)	73.4	77.7
Saturated acids per cent. (corrected)	20.6	16.4
Unsaturated acids per cent. (corrected)	74.6	78.7
Iodine number of unsaturated acids	121.8	118.2

The percentages of oleic and linolic acids were determined by analyzing the bromine addition derivatives of the unsaturated acids.

The saturated acids were converted into the methyl esters and fractionally distilled *in vacuo*. The constituent acids in the various fractions were separated by fractional crystallization from alcohol and identified by melting points and elementary analyses. The percentages were calculated from the mean molecular weights, determined by saponification.

The percentage composition of the saturated acids from the two oils is practically the same, but the oil from the Spanish type peanuts contains 20.6 per cent. of this saturated acid mixture, while the oil from the Virginia type contains only 16.4 per cent.

The composition of these two oils was found to be as follows:

		Oil from Spanish type peanuts per cent.	Oil from Virginia type peanuts per cent.
Glycerides of	Oleic acid	52.9	60.6
	Linolic acid	24.7	21.6
	Palmitic acid	8.2	6.3
	Stearic acid	6.2	4.9
	Arachidic acid	4.0	3.3
	Lignoceric acid	3.1	2.6
Unsaponifiable matter		0.2	0.3

Hypogæic acid was carefully tested for but could not be detected.

[3] Iodine number 4.8.

[4] Iodine number 7.1.

NOTES FROM THE U. S. BUREAU OF MINES.*

ROCK STRATA GASES IN MINES OF THE EAST TINTIC DISTRICT, UTAH.

By G. E. McElroy.

THE development of certain mines in the East Tintic mining district, Utah, has been hindered considerably by the presence in the rock strata of heavy irrespirable gases which at times flood the lowest working places, as well as by abnormally high rock temperatures in the lower horizons. A study of these features was completed in the spring of this year.

The affected mines are on or near the crest of a large anticline composed of sedimentary rocks, almost entirely overlain by lava flows. The sedimentary rocks consist of a great thickness of quartzite separated from overlying limestones of considerable but varying thicknesses by a formation of pyritic shales, 300 to 500 feet thick, containing interbedded limestones.

As a rule, these heavy gases peculiar to this district, are not encountered in mining until the quartzite is pierced, although they occur in places in fissured zones in the overlying limestones. Abnormally high rock temperatures also appear to be limited to horizons close to the quartzite.

Calculation of samples to an air-free basis shows that the pure gas is primarily a mixture of carbon dioxide and nitrogen with the carbon dioxide in excess. The gas also contains some sulphur dioxide. The gas is 1.25 to 1.40 times as heavy as the adjacent air. The difference in weight causes the gas to drop to the lowest points, and form accumulations or pools. Diffusion with the mine air is relatively slow in quiet atmospheres but increases as the air motion is increased. The evidence gathered from the mines affected indicates that the heavy gases have resulted from oxidation of sulphides.

The necessity for good air motion at working places and the relatively slow rate of gas inflow, indicate that the best remedy is dilution of the gas inflow with large volumes of air by mechanical ventilation. Further details are given in a recent report issued by the bureau.

* Communicated by the Director.

PRESSURE-VOLUME DEVIATION OF METHANE, ETHANE, PROPANE AND CARBON DIOXIDE AT ELEVATED PRESSURES.

By G. A. Burrell and G. W. Jones.

As a part of the work which the Bureau of Mines carried out in 1916 and 1917 pertaining to the compressibility of natural gas, it became necessary to determine the pressure-volume relations of several of the paraffin hydrocarbons of which natural gas is composed.

Results of the work on natural gas were published in *Technical Papers 131* and *158*, and curves were given of pressure-volume deviations of the gases, methane, ethane, propane, and carbon dioxide at high pressures. The original experimental data on these gases, however, were not published.

In view of many inquiries which the Bureau has received with reference to the original data on these gases, and the importance of the pressure-volume relations from which it is possible to calculate the deviation of any natural gas whose composition is known, the original data as determined by Burrell and Robertson have been issued in mimeograph form.

The apparatus and method of procedure used for determining the pressure-volume relation is described in *Technical Papers 131* and *158*. The methods used in preparing the gases for pressure-volume deviations at elevated pressures were as follows: Methane, fractional distillation of natural gas at low temperatures and pressures; ethane, electrolysis of sodium acetate; propane, action of propyl iodide on a zinc-copper couple; carbon dioxide, action of sulphuric acid on a solution of potassium bicarbonate. In preparing these gases, extreme care was taken to rid them of all impurities. In every case, the final method of purification was fractional distillation at low temperatures and pressures.

FOURTH SEMI-ANNUAL MOTOR GASOLINE SURVEY.

By N. A. C. Smith.

THE Bureau of Mines motor gasoline surveys have been conducted in January and July, during 1920 and 1921. The Bureau has obtained and analyzed samples of gasoline representative of that marketed in the larger cities. These surveys have indicated that the gasoline on the market during the winter months is more volatile than that sold during the summer months. Naturally,

the motorist desires a more volatile gasoline in the cold winter months, as it affords greater ease in starting.

The fourth semi-annual motor gasoline survey, conducted during the month of July, shows an interesting relation between the market price and the quality of motor gasoline. This is particularly evident if figures obtained to-day are compared with those of a year ago. At the time the Bureau of Mines conducted its summer survey of motor gasoline last year, the average tank wagon price of gasoline was 28.2 cents per gallon. This year it was 21.2 cents, a drop of practically 25 per cent.

The nine cities in which samples of gasoline were collected this summer and the tank prices are as follows:

Motor Gasoline Tank Wagon Prices (in cents per gallon).

City	July, 1920	July, 1921	Difference
New York, N. Y.	30.0	24.0	6.0
Washington, D. C.	28.5	22.0	6.5
Pittsburgh, Pa.	29.7	22.0	7.7
Chicago, Ill.	26.0	18.0	8.0
New Orleans, La.	28.0	17.5	10.5
St. Louis, Mo.	25.7	17.4	8.3
Denver, Colo.	31.0	22.0	9.0
Salt Lake City, Utah.	31.5	25.0	6.5
San Francisco, Calif.	23.5	23.0	0.5
Average	28.2	21.2	7.0

In spite of this drop in price, the quality of gasoline to-day is much better than it was last summer, in fact, the average gasoline to-day is almost identical in quality with the average gasoline sold last winter. Tabulated details are given in a recent publication of the Bureau.

Hydro-Electric Power. (*Electrician*, Sept. 2, 1921.)—In Reykjavik, Iceland, there has recently been opened an electric power plant with two dynamos of 1000 and 500 horsepower respectively. There are two water-power companies in the island, the Danish-Islandic and the Norwegian-Islandic, which control streams capable of furnishing millions of horsepower. The local problem is the finding of a market for the immense available power.

In New South Wales favorable legislation has stimulated hydro-

electric development. Plans have been prepared for the Barren Jack and the Nymboida installations while a considerable number of municipal projects are under way. The question of the utilization of the water-power resourses of the state is pressing. The government has had to refuse an application for 5000 H. P. for the manufacturing of aluminium and there are frequent inquiries for power from persons connected with electrothermic and electrolytic manufacturing.

The power station at Trollhattan in Sweden has 13 turbines with an aggregate of 166,000 H. P. At Mottala in the same country, work was begun on the station in October, 1918, and will be completed in April, 1922. Eventually there will be five turbines, each of 6000 H. P., direct coupled to dynamos developing three-phase current, 50 cycles, at 6000 volts. This will be transformed to 70,000 volts for long distance transmission.

Since Switzerland has neither iron nor coal her industrial success is remarkable. In large measure this is due to the development of the water-power of the country, which indeed was well under way a generation ago. When the war intervened to prevent the customary importation of coal from adjacent countries a fresh impetus was given to such development, with the result that there are now no less than 6870 power stations in this small country, of which 178 have an output of more than 500 H. P. The annual energy furnished by these stations equals that obtainable from 4,000,000 tons of coal.

G. F. S.

Magnetic Susceptibility of Nickel and Cobalt Chloride Solutions. LAURA BRANT. (*Phys. Rev.*, June, 1921.)—A decade ago Pierre Weiss, now of the University of Strasbourg, advanced the suggestion that the magnetic moments of molecules of different elements were whole multiples of an elementary moment to which he applied the name "magneton." The evidence for the existence of such a quantum of magnetic moment has been far from overwhelming with the result that the magneton is still *sub judice*.

The present investigations led to the calculation of the number of magnetons per molecule of nickel and also of cobalt. For the former the number came out 16 in accordance with the previous results of Weiss and Mlle. Bruins. Though the solutions used differed greatly in concentration the calculated number of magnetons per molecule had no greater range than from 15.98 to 16.04.

For cobalt the number came out 24.498 with a range from 24.47 to 24.51. This is, of course, not a whole number. "The number for cobalt presents again the half-magneton already found in the case of other solutions: It would agree with Weiss's theory if the gram-magneton were assigned half the value." G. F. S.

THE FRANKLIN INSTITUTE

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, September 7, 1921.)

HALL OF THE INSTITUTE,
PHILADELPHIA, SEPTEMBER 7, 1921.

MR. CHARLES W. MASLAND *in the Chair.*

The following report was presented for first reading:
No. 2768. "Once-Over" Tiller.

R. B. OWENS,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, September 14, 1921.)

RESIDENT.

MR. ROLAND L. ANDREAU, Laurel Springs, New Jersey.
MR. ARTHUR KNAPP, United Gas Improvement Company, Philadelphia, Pennsylvania.
MR. STEPHEN H. NOYES, Civil Engineer, Room 746, City Hall, Philadelphia, Pennsylvania.
MR. RUFUS H. SANFORD, Librarian, The Baldwin Locomotive Works, Philadelphia, Pennsylvania.
MR. HOWARD STOERTZ, Electric Storage Battery Company, 19th Street and Allegheny Avenue, Philadelphia, Pennsylvania.
MR. SOLOMON WEINBERG, Sunderland House, 35th Street and Powelton Avenue, Philadelphia, Pennsylvania.

NON-RESIDENT.

MR. ARTHUR BLACKBURN, 5905 York Road, Baltimore, Maryland.
MR. E. Z. CROW, P. O. Drawer, 428, Chickasaw Branch, Mobile, Alabama.
MR. JOHN STUART EASON, 819 University Avenue, N. E., Minneapolis, Minnesota.
MR. WILLIAM H. GESELL, 235 Christopher Street, Montclair, New Jersey.
DR. W. J. HUMPHREYS, Weather Bureau, Washington, District of Columbia.

MR. D. BRUCE MORGAN, 805 Gotham National Bank Building, New York City, New York.

CHANGES OF ADDRESS.

MR. CARL P. BIRKINBINE, Commercial Trust Building, Room 800, Philadelphia, Pennsylvania.

MR. HENRY M. ELLIOT, 5 Northern Boulevard, Albany, New York.

MR. RUDOLPH HERING, 40 Lloyd Road, Montclair, New Jersey.

DR. HARRY F. KELLER, 103 W. Upsal Street, Germantown, Philadelphia, Pennsylvania.

MAJOR C. W. MCMEEKIN, 1632 Spruce Street, Berkeley, California.

MR. LEGRAND PARISH, President, American Arch Company, Inc., 17 East 42nd Street, New York City, New York.

PROFESSOR I. M. RAPP, State University, Missoula, Montana.

DR. W. F. RITTMAN, care of Carnegie Tech., Pittsburgh, Pennsylvania.

MR. JOHN STONE STONE, 4811 Panorama Street, San Diego, California.

MR. J. STEPHEN VAN DER LINGEN, Physical Laboratory, The Johns Hopkins University, Baltimore, Maryland.

NECROLOGY.

Charles Otis Bond was born in Iowa, in 1871 and died at Collegeville, Pennsylvania, August 2, 1921.

He was graduated from the United States Naval Academy and served as a lieutenant during the war with Spain. He became associated with the United Gas Improvement Company in 1897 and was for a number of years the the head of the physical and photometrical laboratory of the Company at Point Breeze. During this time he specialized in standardizing apparatus for testing the heating and illuminating qualities of gas and invented improved devices for this purpose, one of which, a "dewpoint" hygrometer, is of special value for determining the lowest temperature that gas reaches in the mains.

Mr. Bond became greatly interested in the subject of illumination and was known as an authority on gas as an illuminant. This was recognized by his election as national president of the Illuminating Engineering Society in 1914.

He became a member of The Franklin Institute in 1903.

Henry F. Colvin was born at Plainfield, Connecticut, on July 6, 1838 but at an early age his family removed to Scott, Pennsylvania. While still a youth he was for a time engaged with his father in the gunsmithing business. When he was eighteen years old, he entered the employ of the Delaware, Lackawanna and Western Railroad and three years later became an engineer on the same road. Finding locomotive running too great a physical strain, he retired from the service and connected himself with one of the large locomotive manufacturing plants of New England. In 1876, he associated himself with the Rue Manufacturing Company of Philadelphia and two years later removed to Philadelphia and became general manager of the company, which position he held for over thirty years, until his retirement from active life.

He devised several improvements in injectors and steam-jet apparatus and was also the inventor of a two-cylinder cross-compound and a tandem-compound locomotive.

Mr. Colvin became a member of The Franklin Institute on September 3, 1884 and in 1892 was elected a member of its Committee on Science and the Arts, serving continuously since that time. He took an active part in the work of this Committee and was also intensely interested in the success of all the Institute's undertakings.

Mr. Wharton Barker, Port Royal Avenue, Roxboro, Philadelphia, Pennsylvania.

Mr. James G. Davis, The United Gas Improvement Company, Broad and Arch Streets, Philadelphia, Pennsylvania.

Mr. W. W. Frazier, Drexel Building, Philadelphia, Pennsylvania.

Mr. Thomas W. Sparks, 4100 Walnut Street, Philadelphia, Pennsylvania.

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PURCHASES.

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HARDING, M. C. [Ed.].—Correspondence de H. C. Oersted, 2 vols. 1920.

HELMHOLTZ, H. VON.—Handbuch der Physiologischen Optik, 3 vols. 1909–11.

LORIA, GINO E VASSURA, GIUSEPPE [Ed.].—Opere di Evangelista Torricelli, 3 vols. 1919.

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GIFTS.

Adamson, Daniel and Company, Ltd., Catalogue on Compressed Air as Applied to Sewerage, Sewage Disposal and Water Supply. London, England, 1921. (From the Company.)

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American Petroleum Institute, Bulletin No. 132, Addresses Delivered at the November, 1920, Meeting of the Institute; Bulletin 145, Report of the Secretary and Counsel; Bulletin No. 152, Statistical Tables Relative to Petroleum Situation; Bulletin 154, Estimates of Daily Average Crude Oil Production; Bulletin 161, Pipe Line and Tank Stocks; Bulletin 163, Production, Stocks, etc., of Gasoline; Bulletin 164, Production, etc., of Gas and Fuel Oils. New York City, New York, 1921. (From the Institute.)

American Spiral Pipe Works, Catalogue Describing Pipe. Chicago, Illinois, no date. (From the Works.)

Anti-Corrosion Engineerng Company, Inc., Booklet, Water That Won't Rust. New York City, New York, no date. (From the Company.)

Austin Manufacturing Company, Catalogue G, The Austin Motor Sweeper. Chicago, Illinois, no date. (From the Company.)

Autocall Company, Booklet, How to Organize Fire Drills. Shelby, Ohio, 1921. (From the Company.)

Barrett Company, Booklets Describing Road Maintenance with Tarvia. Philadelphia, Pennsylvania, 1921. (From the Company.)

Bastian-Blessing Company, Catalogue No. 23, Reco Welding and Cutting Apparatus. Chicago, Illinois, no date. (From the Company.)

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George Washington University, Catalogue 1920–1921. Washington, District of Columbia, 1921. (From the University.)

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New York Central Railroad Company, Report of the Board of Directors, for 1920. New York City, New York. (From the Company.)

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Phosphor Bronze Company, Ltd., Catalogue describing various applications of Phosphor Bronze. London, England, 1921. (From the Company.)

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Shoe and Leather Reporter Company, Annual Catalogue for 1921. Boston, Massachusetts, 1921. (From the Company.)

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Sturtevant, B. F., Company, Catalogue No. 257, Positive Pressure Blowers, Bulletins Nos. 258 and 260. Boston, Massachusetts, no date. (From the Company.)

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

Report No. 112, Control in Circling Flight by F. H. Norton and E. T. Allen. 22 pages, illustrations, quarto. Washington, Government Printing Office, 1921.

This investigation was undertaken by the Committee at the Langley Memorial Aeronautical Laboratory for the purpose of developing instruments that would record the forces and positions of all three controls, and to obtain data on the behavior of an airplane in turns. All the work was done on a standard rigged JN4H (airplane No. 2 of N.A.C.A., Report No. 70). It was found that the airplane was longitudinally unstable and nose heavy; that it was laterally unstable, probably due to too little dihedral; and that it was directionally unstable, due to insufficient fin area, this last being very serious, for in case of a loss of rudder control the airplane immediately whips into a spin from which there is no way of getting it out. On the other hand, it was found possible to fly quite satisfactorily with the rudder locked, and safely, though not so well, with the ailerons locked. The value of Y_v was obtained in free flight, and when the effect of the propeller was subtracted, the agreement with the model test was excellent, but with the propeller revolving at 1350 the value of Y_v was nearly doubled. The value of L_v and N_v were little affected by the slipstream, but their values do not agree with the model test.

Report No. 114, Some New Aerodynamical Relations by Max M. Munk. 13 pages, illustrations, quarto. Washington, Government Printing Office, 1921.

This report contains three new relations extending the modern theory of aeronautics, intended to be applied in some later papers. They deal with phenomena in a frictionless fluid.

The first part contains a relation between the power absorbed by an aerofoil and the power absorbed by a propeller. In the second part the exactness of the ordinary formula for the induced drag of an aerofoil is examined and the error is determined.

In the third part the author shows that for the calculation of the air forces on bodies of considerable volume the imaginary sources and sinks equivalent to the flow around the body can be used in the same way as vortices are used for the calculation of lift and induced drag of wings.

PUBLICATIONS RECEIVED.

With the Atom, a popular view of electrons and quanta, by John Mills. 215 pages, illustrations, 12mo. New York, D. Van Nostrand Company, 1921. Price, $2.00 net.

A First Course in Analytical Geometry, Plane and Solid with Numerous Examples, by Charles N. Schmall, B. A. Second edition, enlarged. 338 pages,

illustrations, 12mo. New York, D. Van Nostrand Company, 1921. Price, $2.25.

Industrial Mathematics Practically Applied, an instruction and reference book for students in manual training, industrial and technical schools, and for home study, by Paul V. Farnsworth. 272 pages, illustrations, 12mo. New York, D. Van Nostrand Company, 1921. Price, $2.50.

U. S. Bureau of Mines: Petroleum Laws of All America, by J. W. Thompson. 645 pages, 8vo. Washington, Government Printing Office, 1921. Price, 40 cents.

Illinois Department of Registration and Education, Division of the State Water Survey: Bulletin No. 16, Chemical and Biological Survey of the Waters of Illinois. Report for years 1918 and 1919. 280 pages, illustrations, 8vo. Urbana, 1920.

U. S. Bureau of Standards: Circular No. 112, Telephone Service. 214 pages, illustrations, 8vo. Washington, Government Printing Office, 1921.

National Advisory Committee for Aeronautics: Technical Notes, No. 62, The Problem of Fuel for Aviation Engines. Lecture given by Professor Kutzbach of Dresden. 21 pages, plate, quarto. No. 63, The Employment of Airships for the Transport of Passengers. Indications on the maximum limits of their useful load, distance covered, altitude and speed, by Umberto Nobile, Director of Italian Aeronautical Construction. 36 pages, 3 plates, quarto. Washington, Committee, 1921.

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